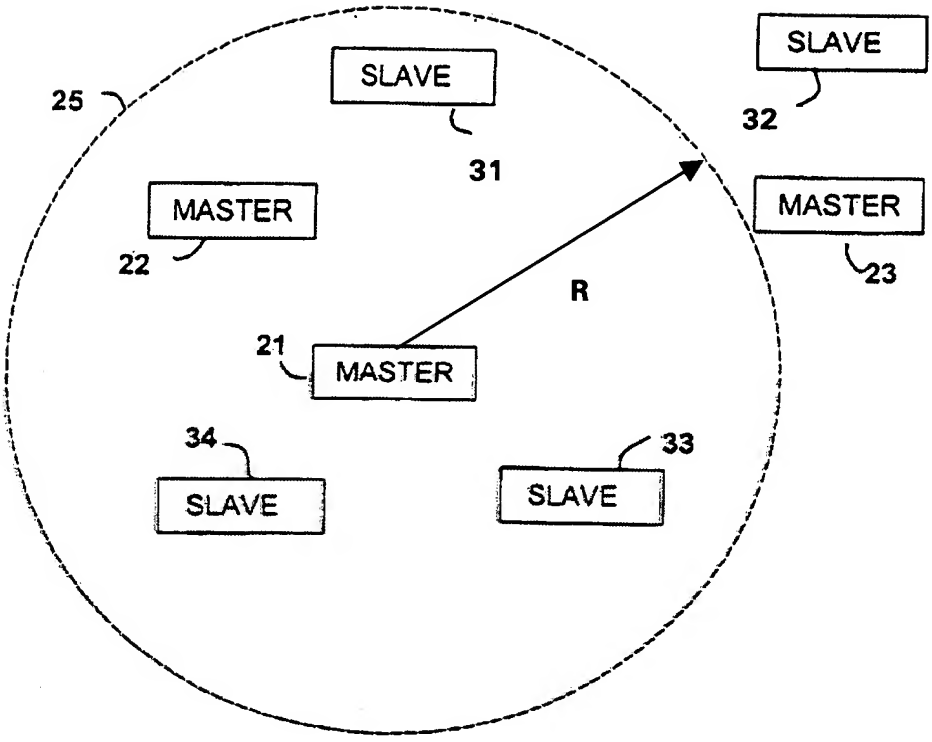
FIG. 1


SLAVE
32
25
SLAVE
31
MASTER
22
MASTER
23
R
21
MASTER
34
33
SLAVE
SLAVE
20

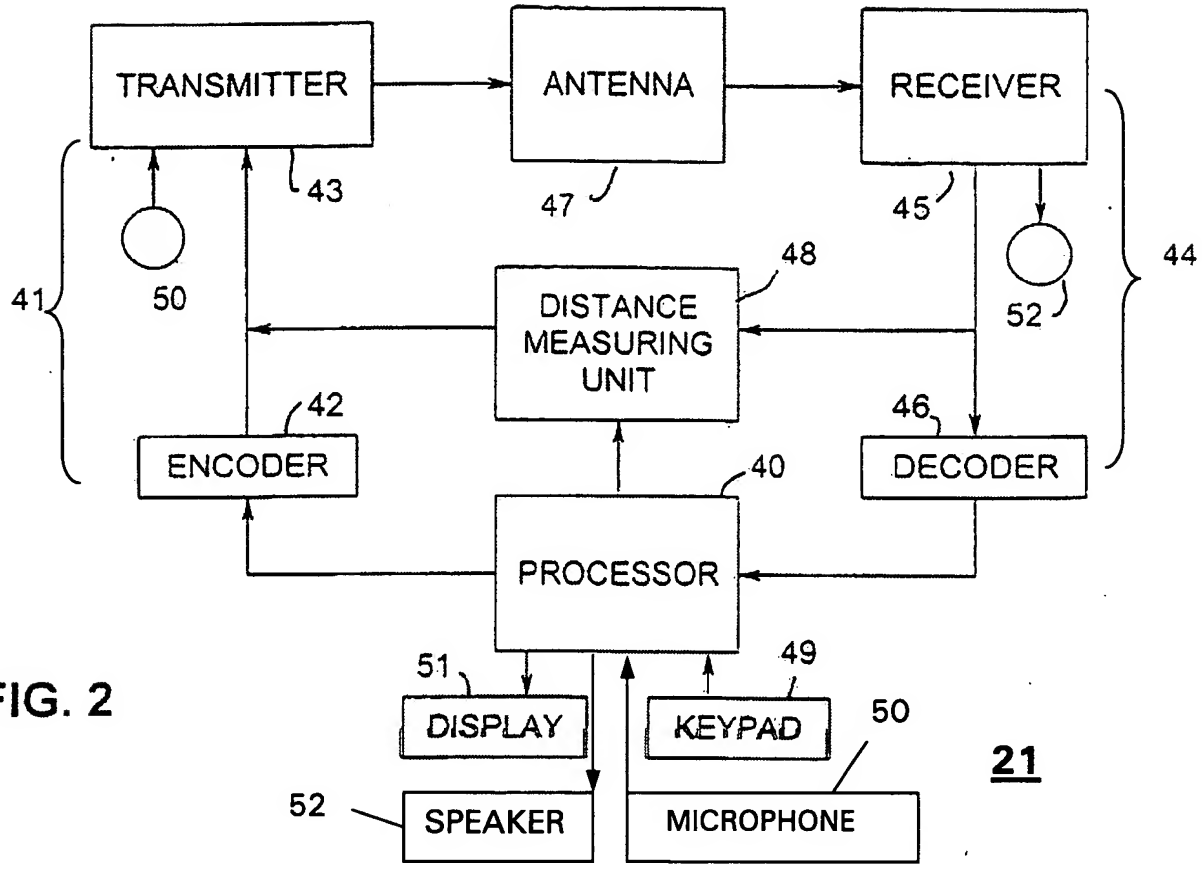

TRANSMITTER
ANTENNA
RECEIVER
43
47
45
41
50
48
44
52
DISTANCE MEASURING UNIT
42
46
ENCODER
DECODER
40
PROCESSOR
51
49
DISPLAY
KEYPAD
50
52
SPEAKER
MICROPHONE
21

FIG. 2

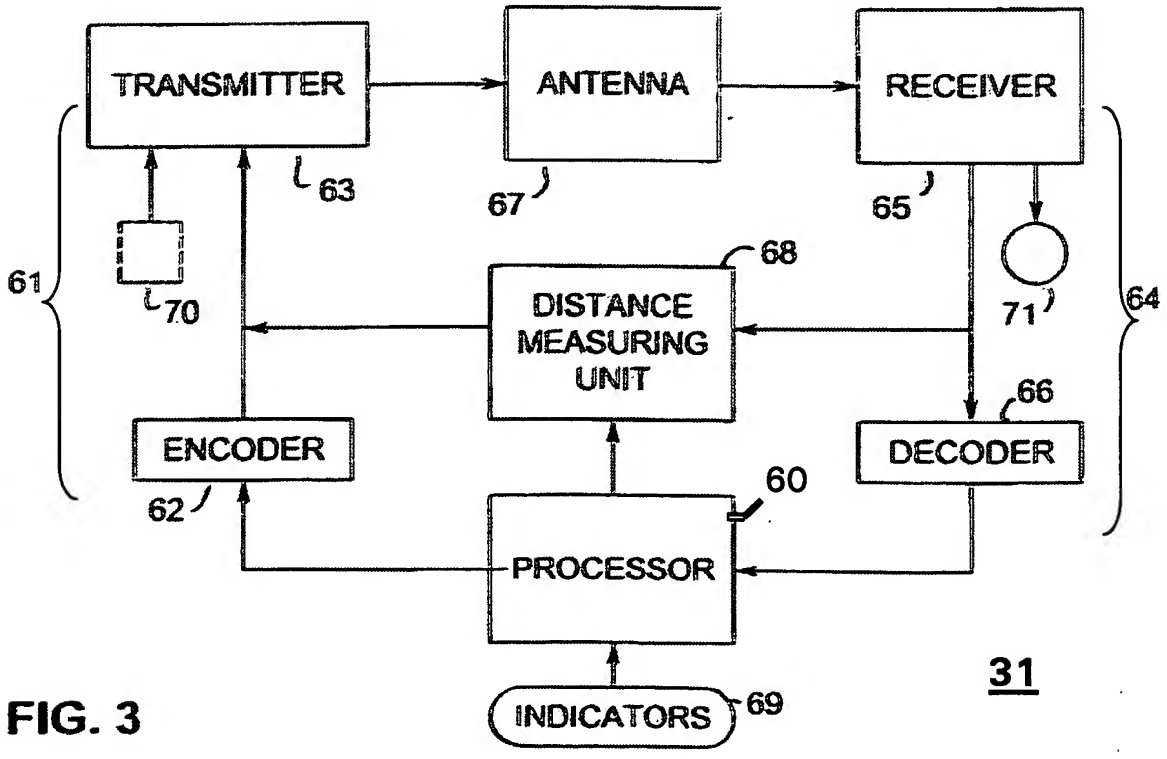

TRANSMITTER
ANTENNA
RECEIVER
63
67
65
61
70
68
71
64
DISTANCE MEASURING UNIT
66
ENCODER
DECODER
62
60
PROCESSOR
31
INDICATORS
69

FIG. 3

FIG. 3A

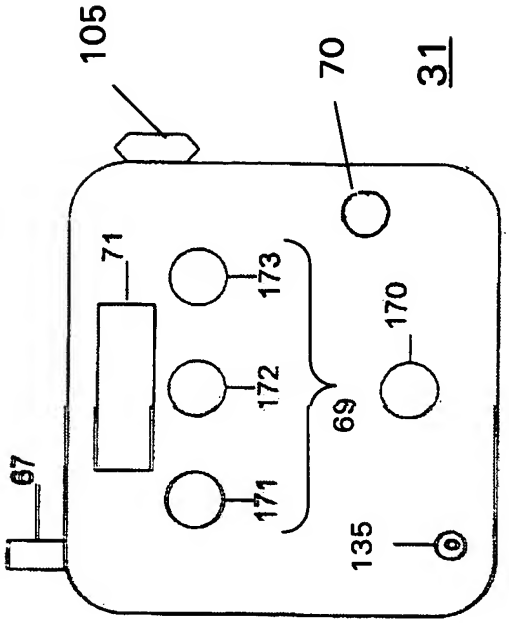
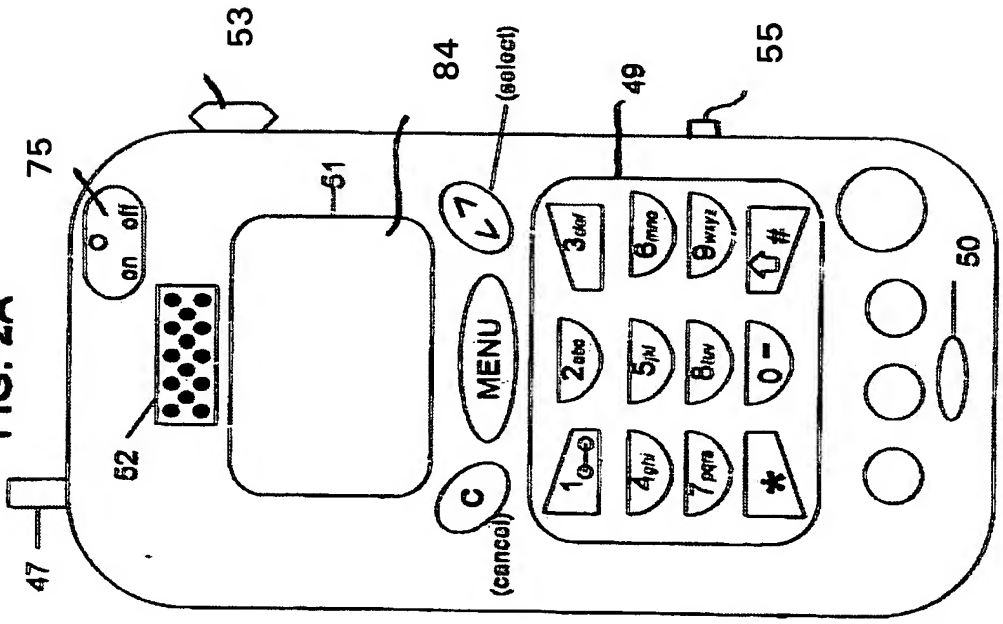

105
70
31
71
173
172
171
69
170
67
135

FIG. 2A


53
84
(select)
55
49
75
51
on off
MENU
52
C
(cancel)
47
50
21

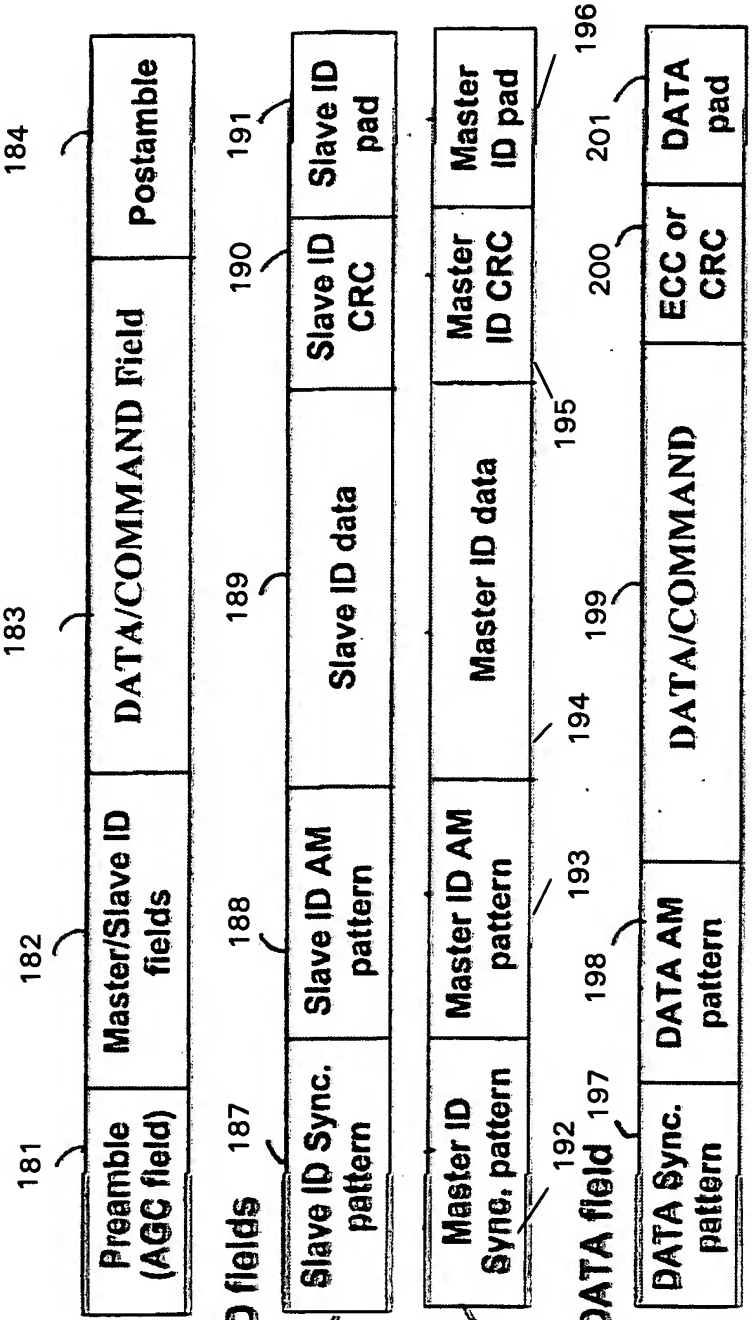


FIG. 3B

FIG. 3C

FIG. 3D

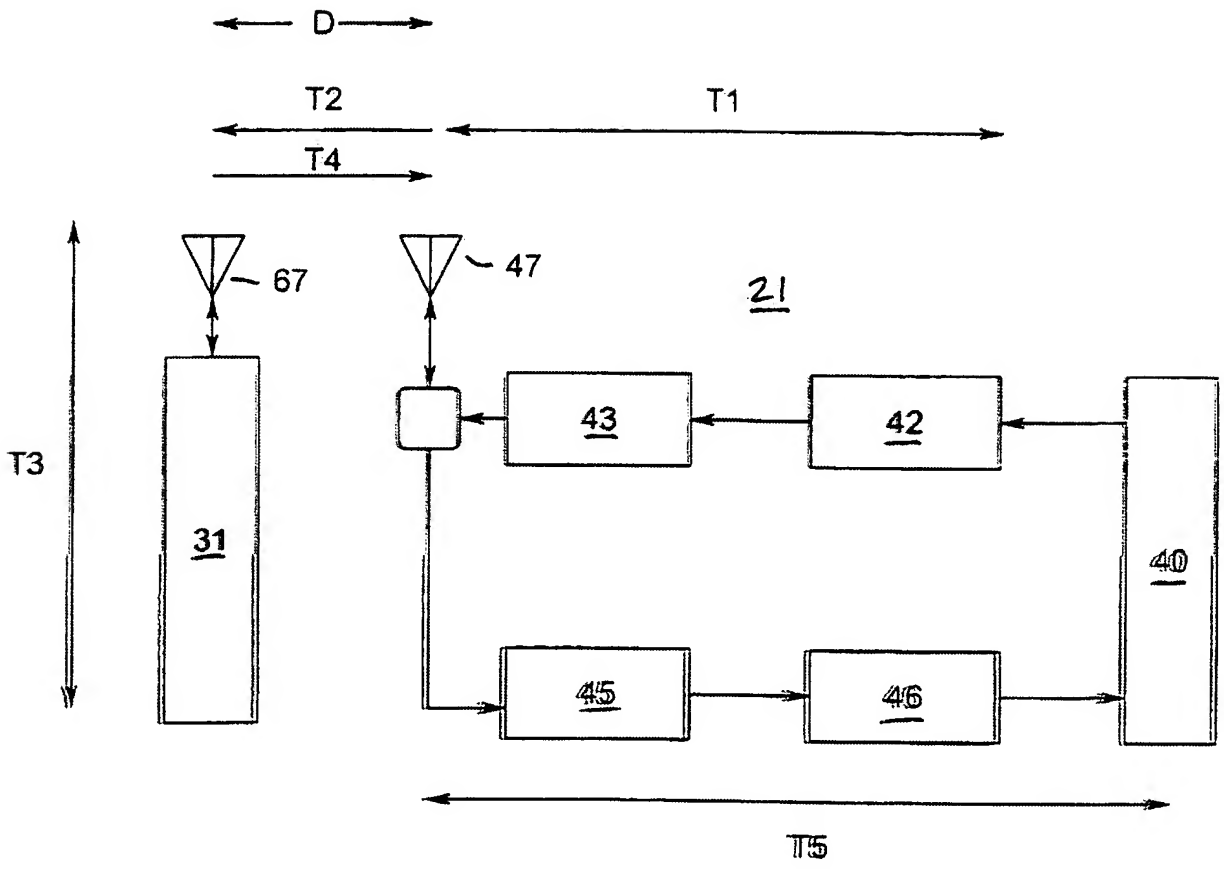


FIG. 4

FIG. 4A

DISTANCE/TIME MEASUREMENT SEQUENCE - OPTION 1

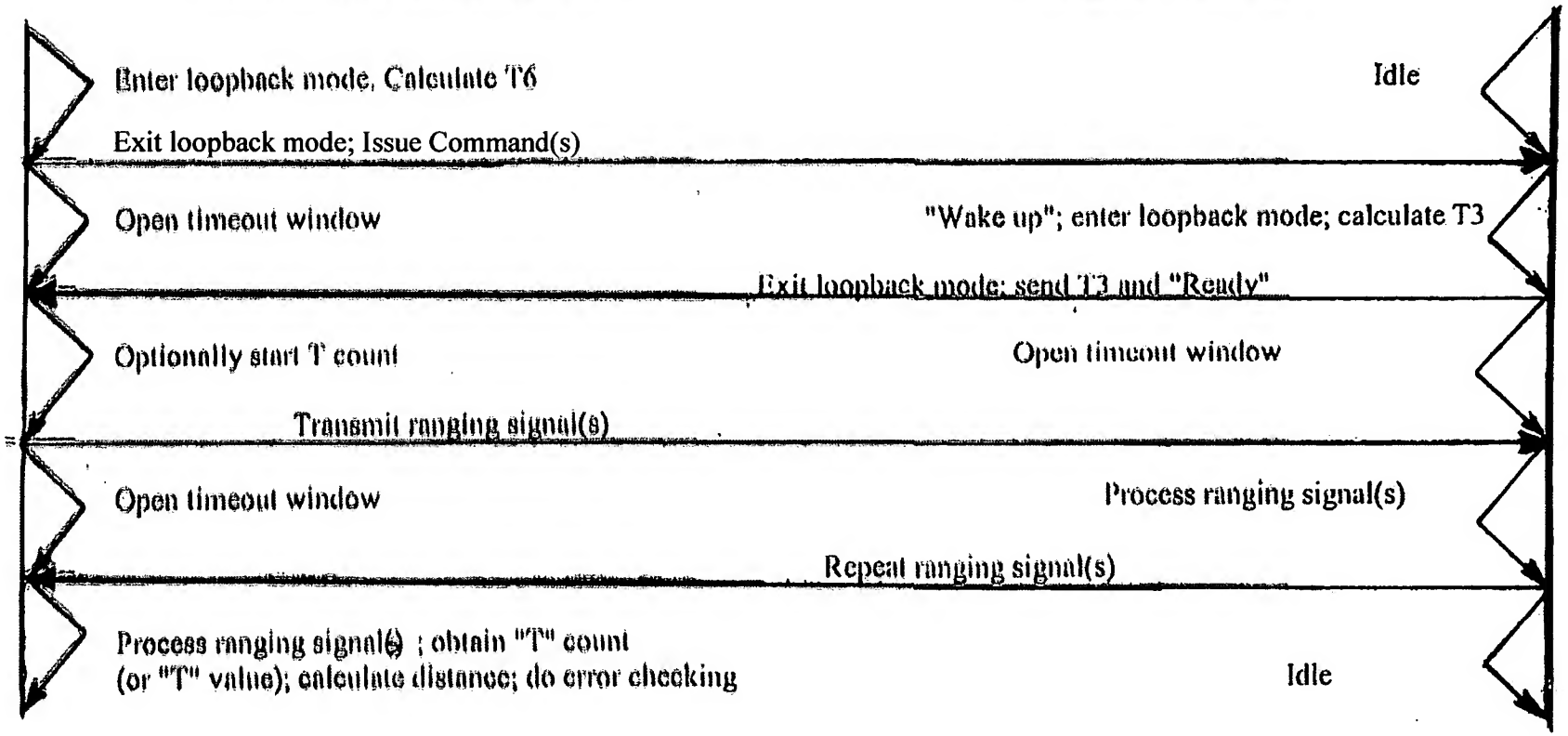
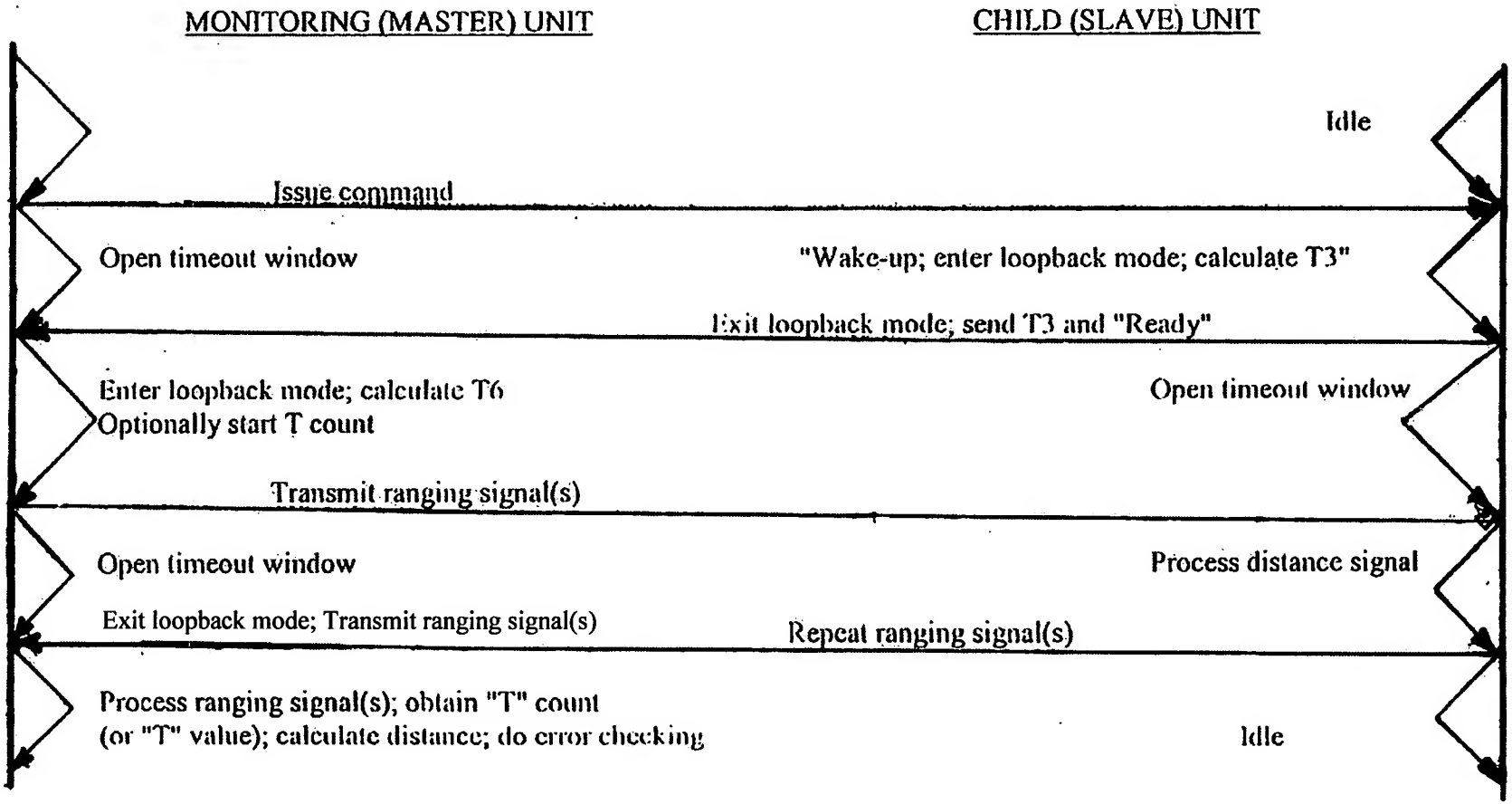


FIG. 4B

DISTANCE/TIME MEASUREMENT SEQUENCE - OPTION 2



7/28 3e

FIG. 5

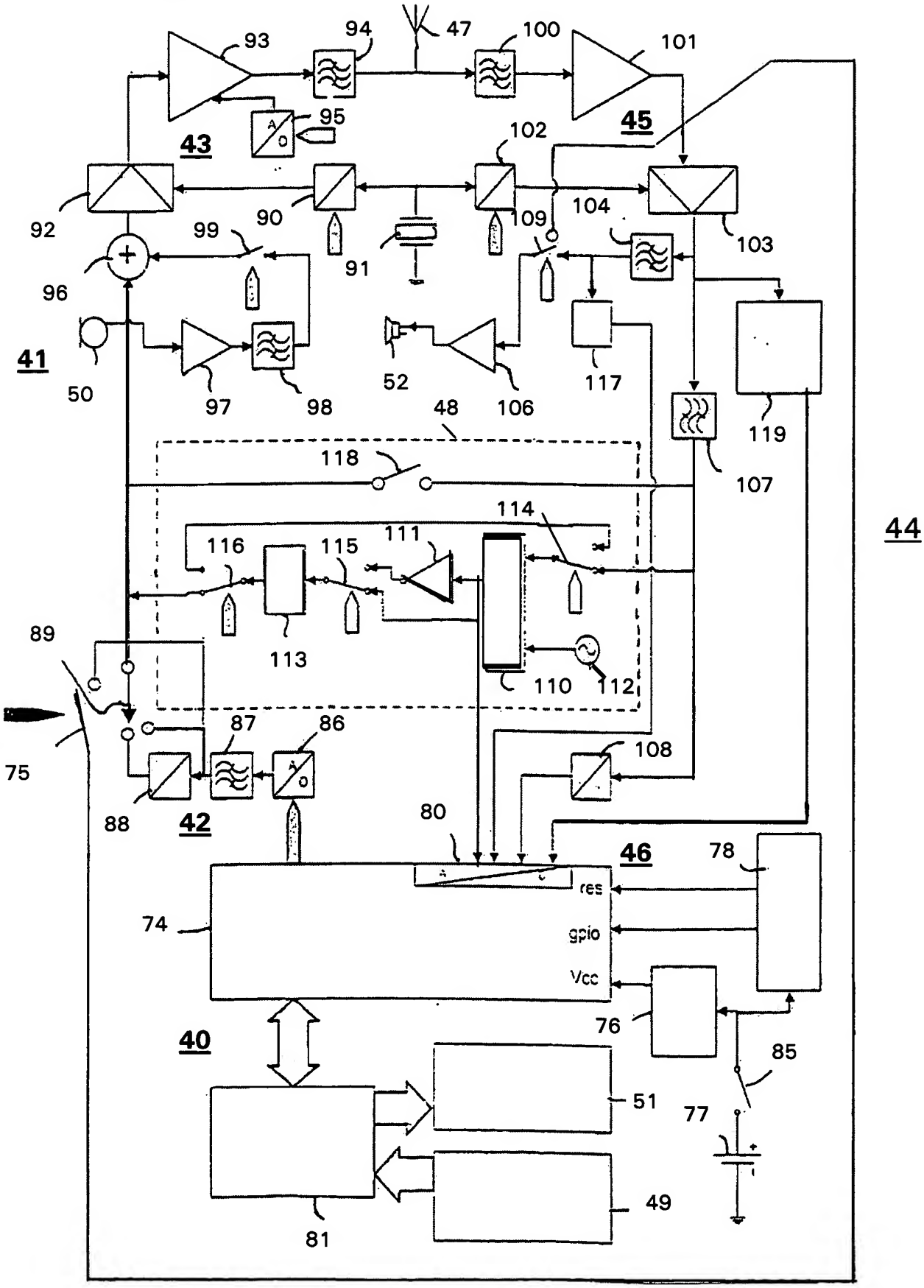
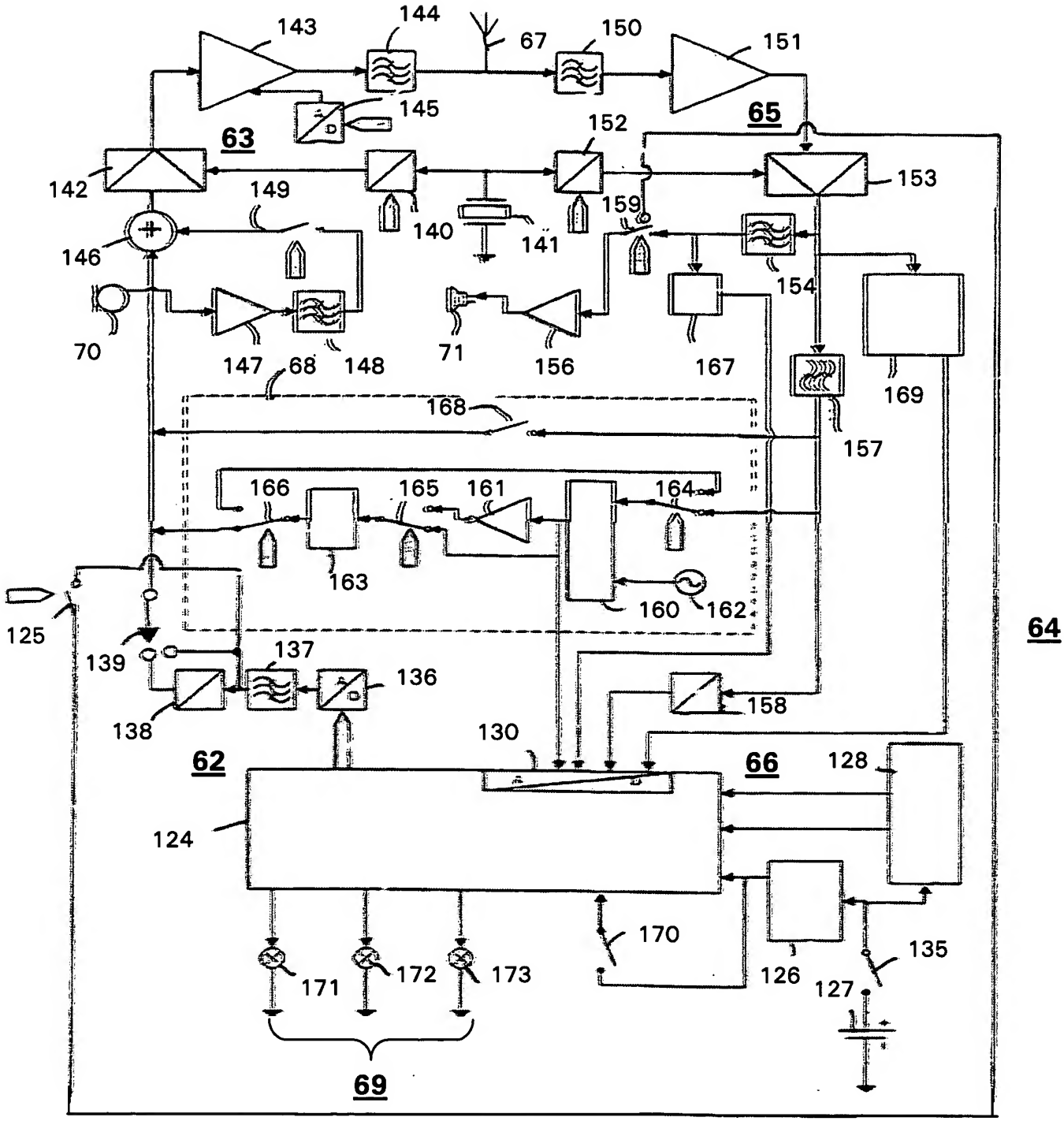

93
94
47
100
101
95
43
45
102
92
90
104
109
103
99
91
96
41
50
97
98
52
106
117
119
48
118
107
114
44
116
115
111
113
110
112
89
75
87
86
108
88
42
80
46
78
74
res
gpio
Vcc
76
85
40
51
77
49
81

FIG. 6A


143
144
67
150
151
145
63
65
152
142
149
153
140
141
159
146
154
70
147
68
148
71
156
167
169
168
157
166
165
161
164
163
160
162
125
64
139
137
136
138
158
130
62
66
128
124
170
135
171
172
173
126
127
69

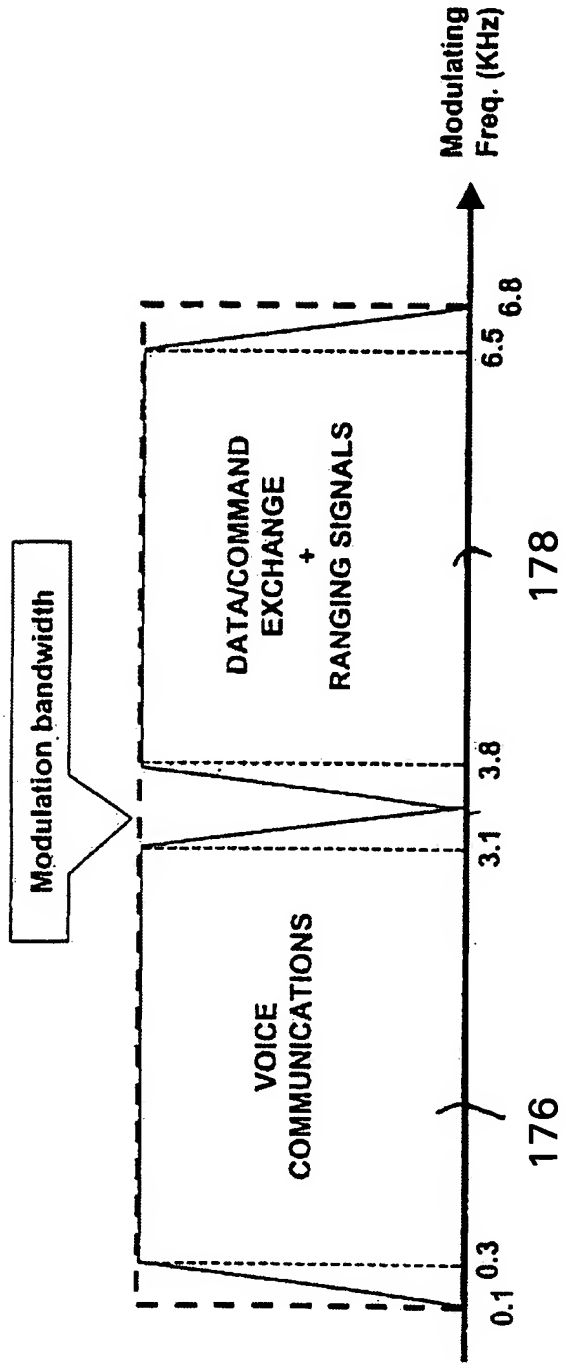

Modulating Freq. (KHz)
Modulation bandwidth
VOICE COMMUNICATIONS
DATA/COMMAND EXCHANGE + RANGING SIGNALS
0.1
0.3
3.1
3.8
6.5
6.8
176
178

FIG. 6B

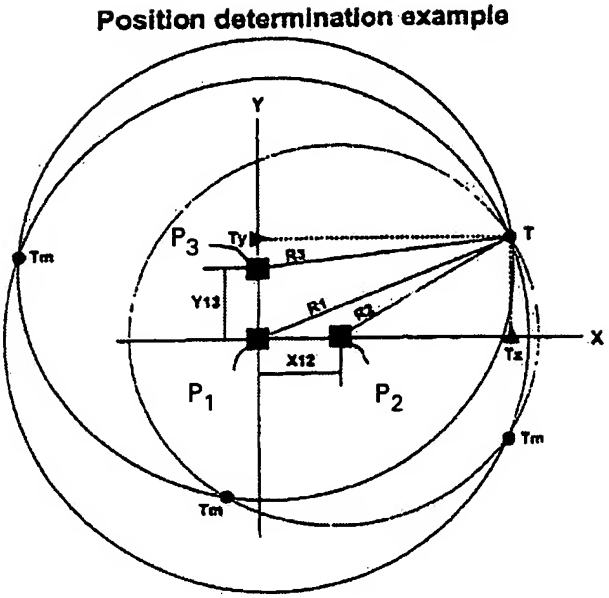

Position determination example
Y
X
T
Tm
Tm
Tm
Tx
Ty
P3
P1
P2
R3
R1
R2
Y13
X12

FIG. 7

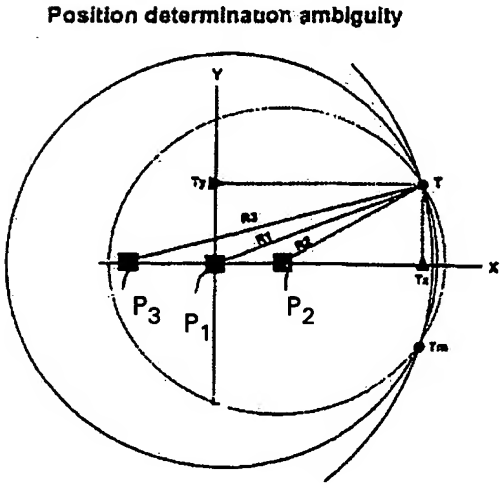

Position determination ambiguity
Y
X
T
Tm
Tx
Ty
P3
P1
P2
R3
R1
R2

FIG. 8

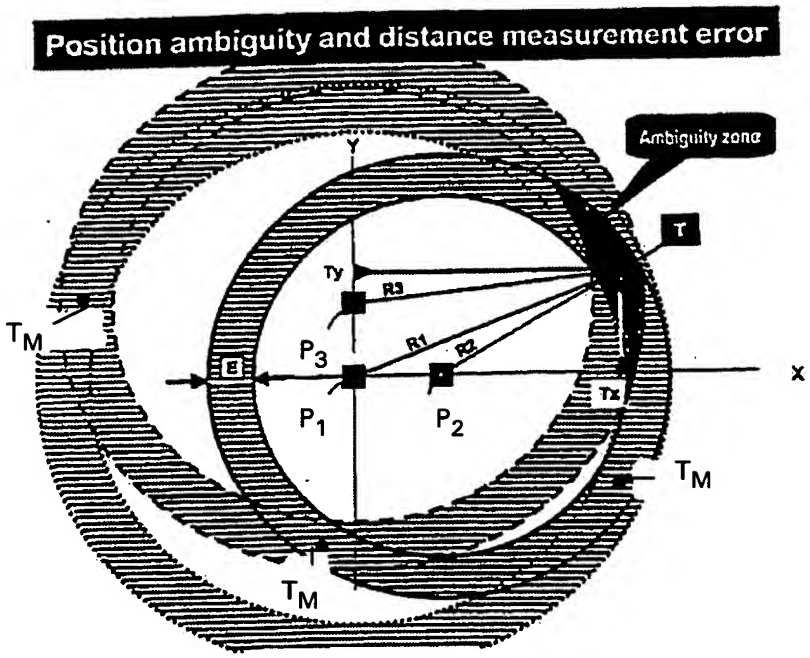

Position ambiguity and distance measurement error
Ambiguity zone
T
Y
Ty
R3
R1
R2
P3
E
x
Tx
P1
P2
TM
TM
TM

FIG. 9

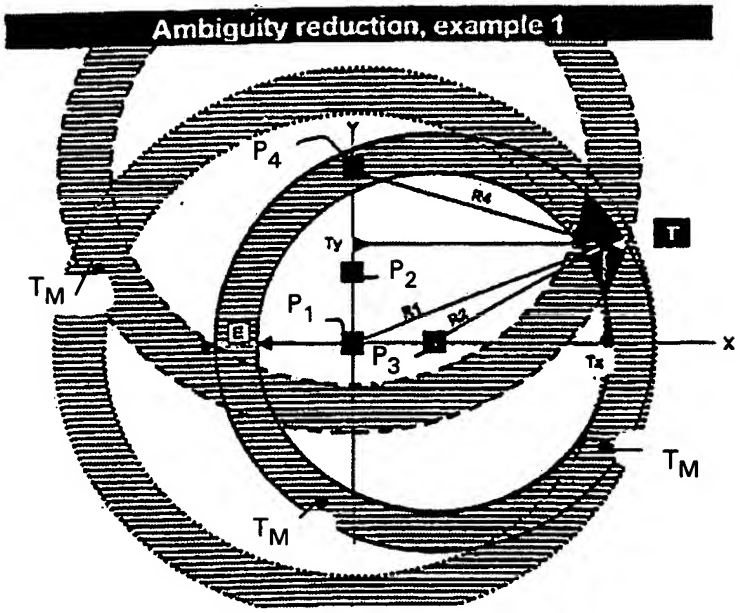

Ambiguity reduction, example 1
P4
Y
R4
T
Ty
P2
TM
P1
R1
R2
E
x
P3
Tx
TM
TM

FIG. 10

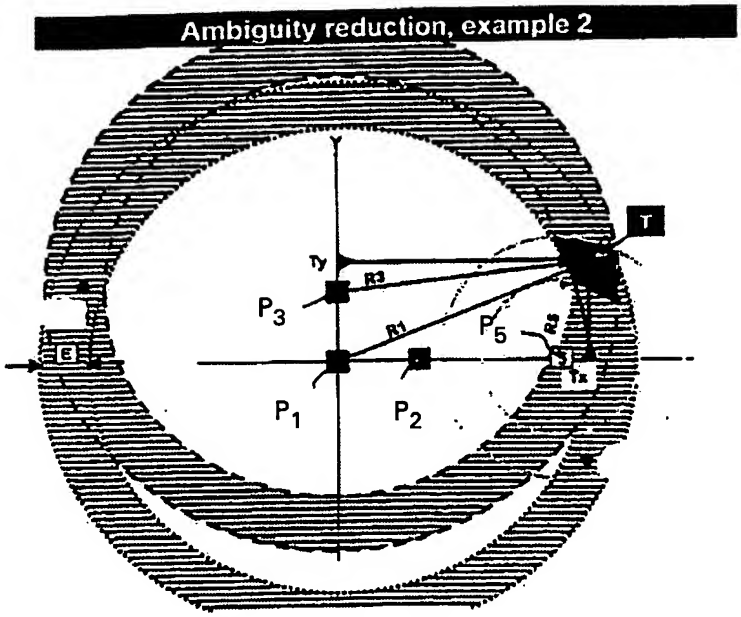


FIG. 11

FIG. 12A

Algorithm 1 flow chart

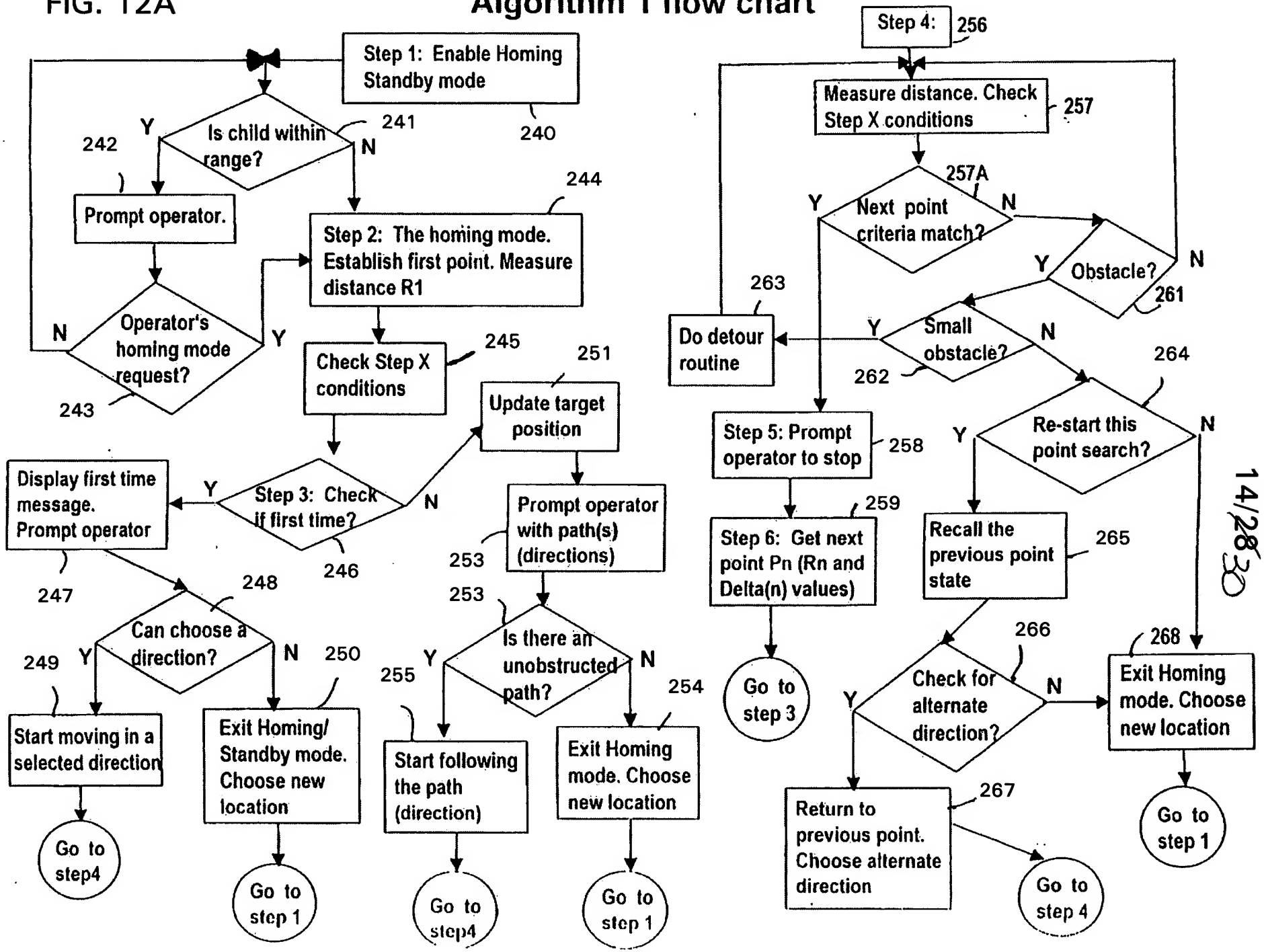
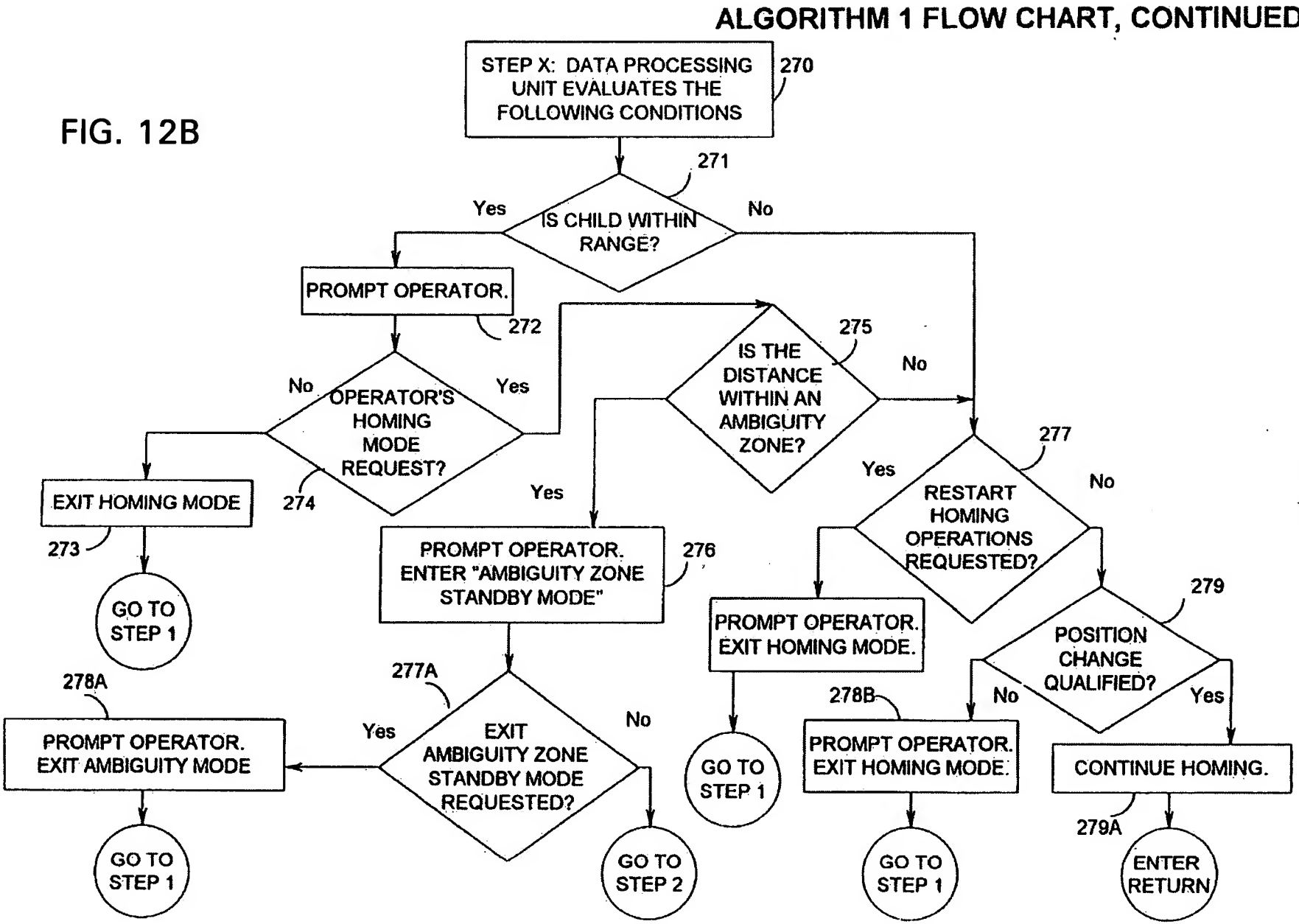


FIG. 12B


ALGORITHM 1 FLOW CHART, CONTINUED
STEP X: DATA PROCESSING UNIT EVALUATES THE FOLLOWING CONDITIONS
270
271
IS CHILD WITHIN RANGE?
Yes
No
PROMPT OPERATOR.
272
OPERATOR'S HOMING MODE REQUEST?
274
No
Yes
EXIT HOMING MODE
273
GO TO STEP 1
IS THE DISTANCE WITHIN AN AMBIGUITY ZONE?
275
No
Yes
PROMPT OPERATOR. ENTER "AMBIGUITY ZONE STANDBY MODE"
276
277A
EXIT AMBIGUITY ZONE STANDBY MODE REQUESTED?
Yes
No
278A
PROMPT OPERATOR. EXIT AMBIGUITY MODE
GO TO STEP 1
GO TO STEP 2
277
RESTART HOMING OPERATIONS REQUESTED?
Yes
No
PROMPT OPERATOR. EXIT HOMING MODE.
GO TO STEP 1
279
POSITION CHANGE QUALIFIED?
No
Yes
278B
PROMPT OPERATOR. EXIT HOMING MODE.
GO TO STEP 1
CONTINUE HOMING.
279A
ENTER RETURN

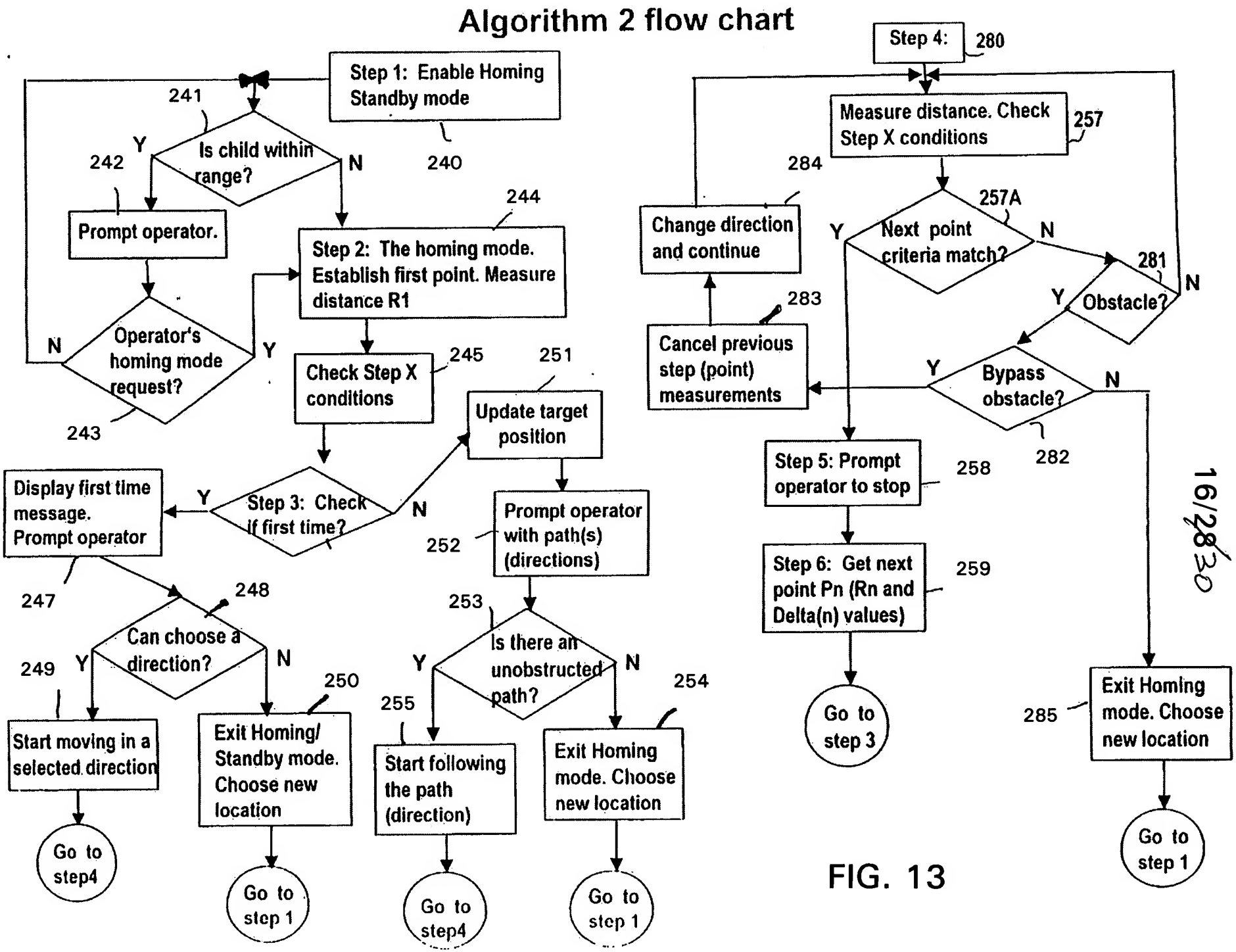

Algorithm 2 flow chart
Step 1: Enable Homing Standby mode
240
241
Is child within range?
Y
N
242
Prompt operator.
Operator's homing mode request?
N
Y
243
244
Step 2: The homing mode. Establish first point. Measure distance R1
245
Check Step X conditions
Step 3: Check if first time?
Y
N
Display first time message. Prompt operator
247
248
Can choose a direction?
Y
N
249
Start moving in a selected direction
Go to step4
250
Exit Homing/ Standby mode. Choose new location
Go to step 1
251
Update target position
252
Prompt operator with path(s) (directions)
253
Is there an unobstructed path?
Y
N
255
Start following the path (direction)
Go to step4
254
Exit Homing mode. Choose new location
Go to step 1
Step 4:
280
Measure distance. Check Step X conditions
257
257A
Next point criteria match?
Y
N
281
Obstacle?
Y
N
282
Bypass obstacle?
Y
N
283
Cancel previous step (point) measurements
284
Change direction and continue
Step 5: Prompt operator to stop
258
Step 6: Get next point Pn (Rn and Delta(n) values)
259
Go to step 3
285
Exit Homing mode. Choose new location
Go to step 1
16/28
30

FIG. 13

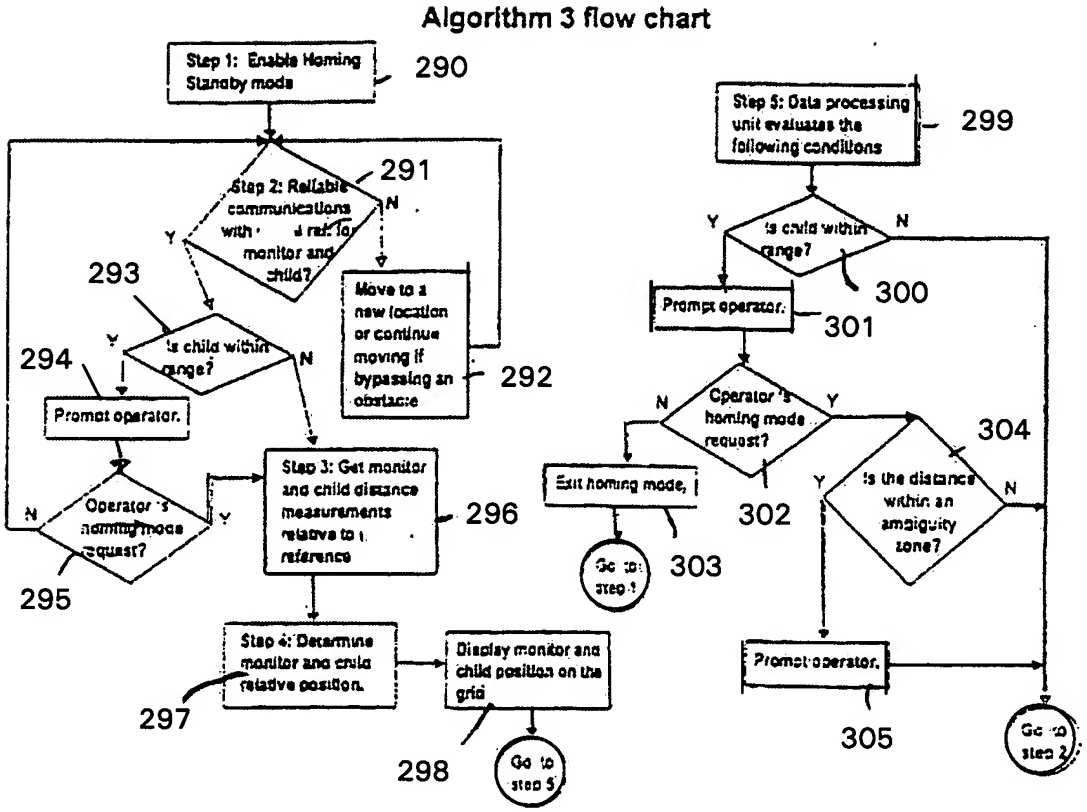

Algorithm 3 flow chart
Step 1: Enable Homing Standby mode
290
Step 2: Reliable communications with ... monitor and child?
291
Y
N
Move to a new location or continue moving if bypassing an obstacle
292
293
Is child within range?
294
Prompt operator.
Operator's homing mode request?
295
Step 3: Get monitor and child distance measurements relative to ... reference
296
Step 4: Determine monitor and child relative position.
297
Display monitor and child position on the grid
298
Go to step 5
Step 5: Data processing unit evaluates the following conditions
299
Is child within range?
300
Prompt operator.
301
Operator's homing mode request?
302
Exit homing mode,
Go to step 1
303
Is the distance within an ambiguity zone?
304
Prompt operator.
305
Go to step 2

FIG. 14

Algorithm 1 homing

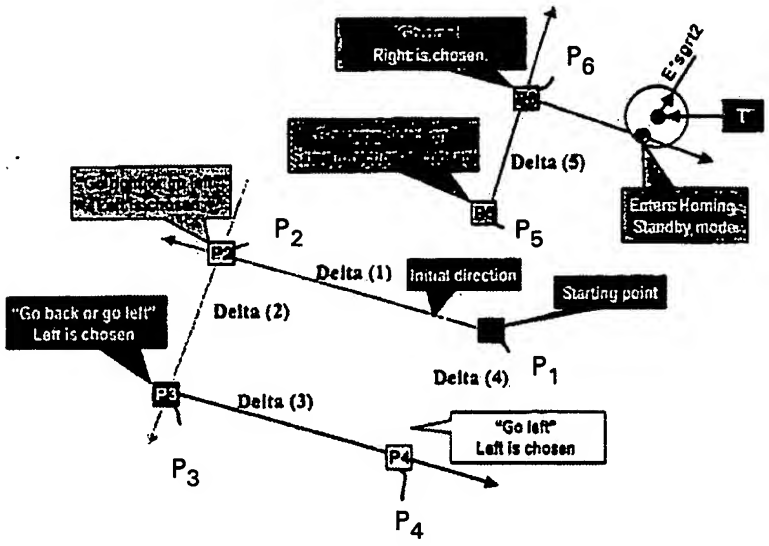
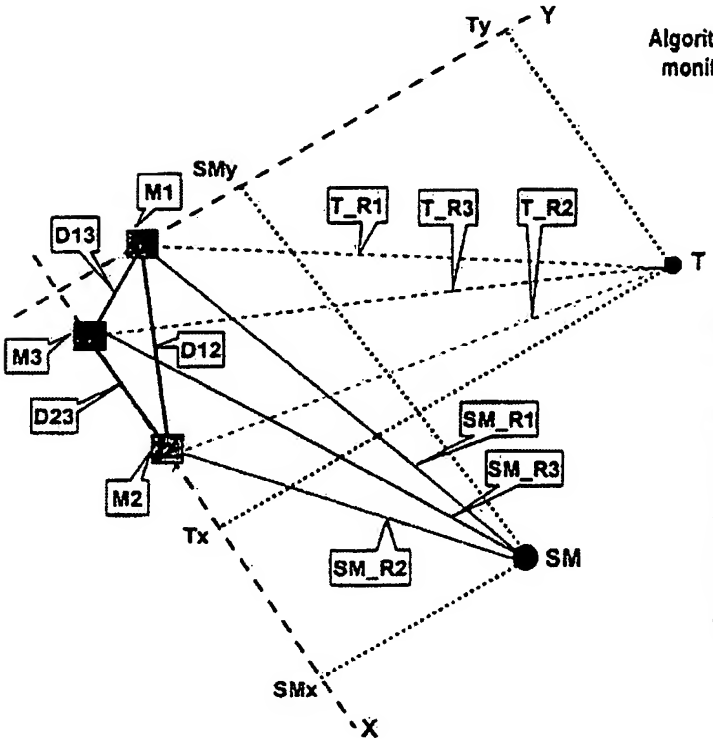


FIG. 15



Algorithm 3 homing. Three stationary monitors example - fixed reference

X, Y - virtual coordinates
SM - "searching monitor"
T - child target
Ty, Tx - target virtual coordinates
SMx, SMy - "Searching Monitor" virtual coordinates
DXX - distance between reference monitors
T_Rn - distance between reference monitors and Target
SM_Rn - distance between reference monitors and the "searching monitor"

FIG. 16

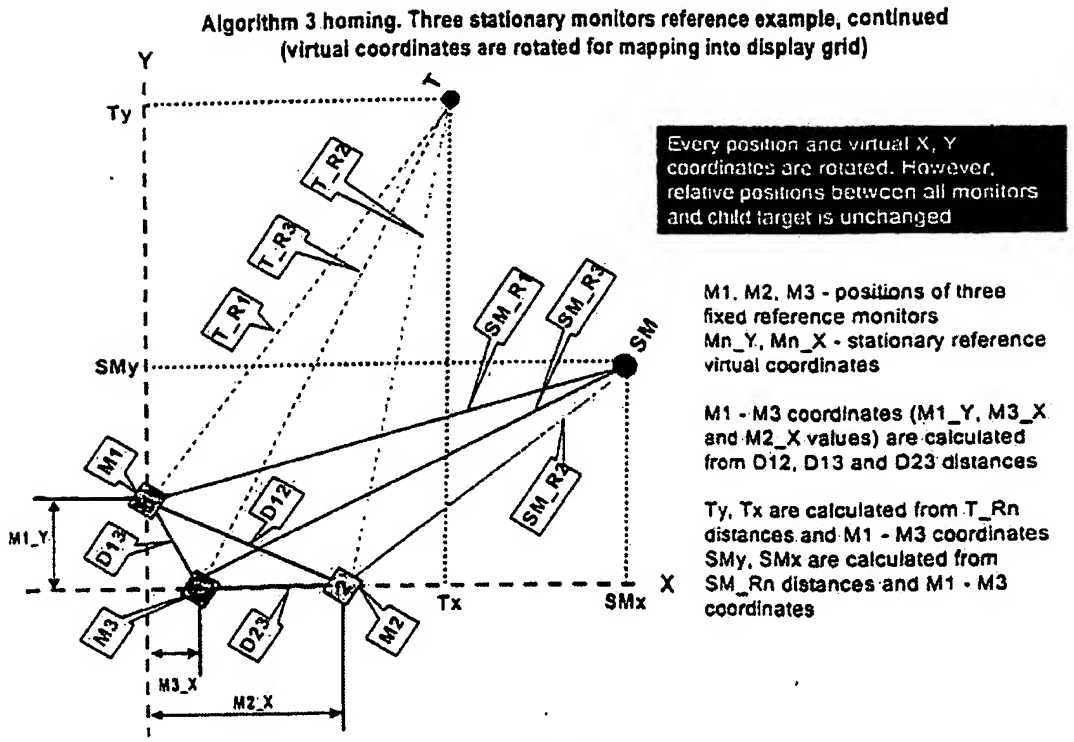

Algorithm 3 homing. Three stationary monitors reference example, continued
(virtual coordinates are rotated for mapping into display grid)
Y
Ty
T
T_R2
T_R3
T_R1
SM_R1
SM_R3
SM
SMy
M1
D12
SM_R2
M1_Y
D13
M3
D23
M2
Tx
SMx
X
M3_X
M2_X
Every position and virtual X, Y coordinates are rotated. However, relative positions between all monitors and child target is unchanged
M1, M2, M3 - positions of three fixed reference monitors
Mn_Y, Mn_X - stationary reference virtual coordinates
M1 - M3 coordinates (M1_Y, M3_X and M2_X values) are calculated from D12, D13 and D23 distances
Ty, Tx are calculated from T_Rn distances and M1 - M3 coordinates
SMy, SMx are calculated from SM_Rn distances and M1 - M3 coordinates

FIG. 17

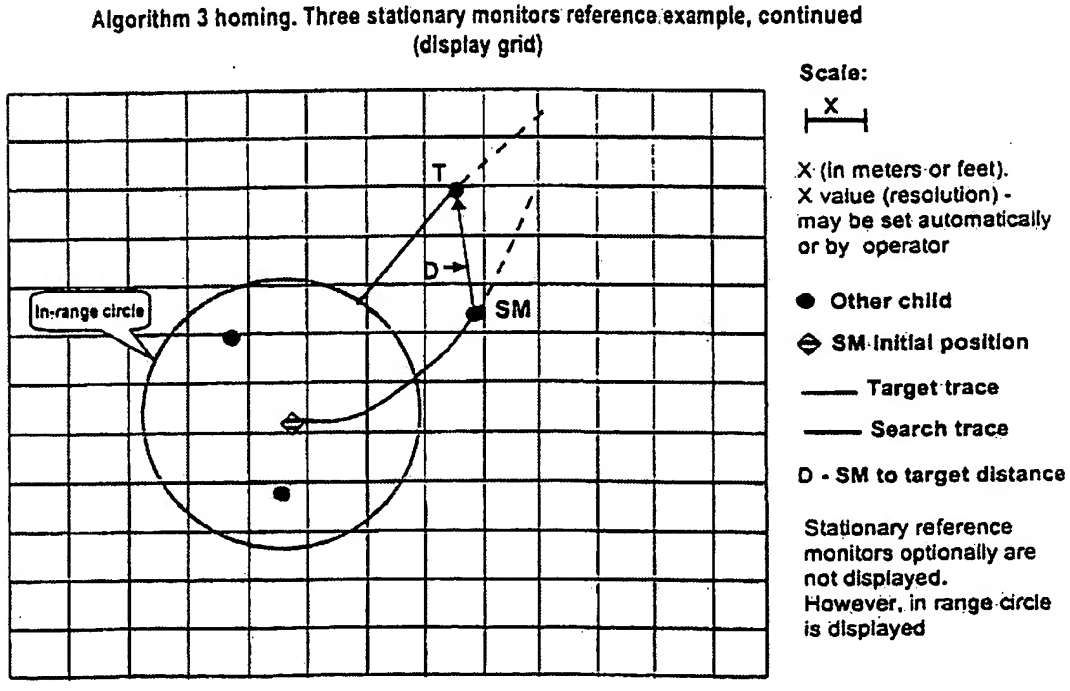

Algorithm 3 homing. Three stationary monitors reference example, continued
(display grid)
T
D
SM
In-range circle
Scale:
X
X (in meters or feet).
X value (resolution) - may be set automatically or by operator
Other child
SM initial position
Target trace
Search trace
D - SM to target distance
Stationary reference monitors optionally are not displayed.
However, in range circle is displayed

FIG. 18

Algorithm 3 homing. Three moving monitors reference example,
(display grid)

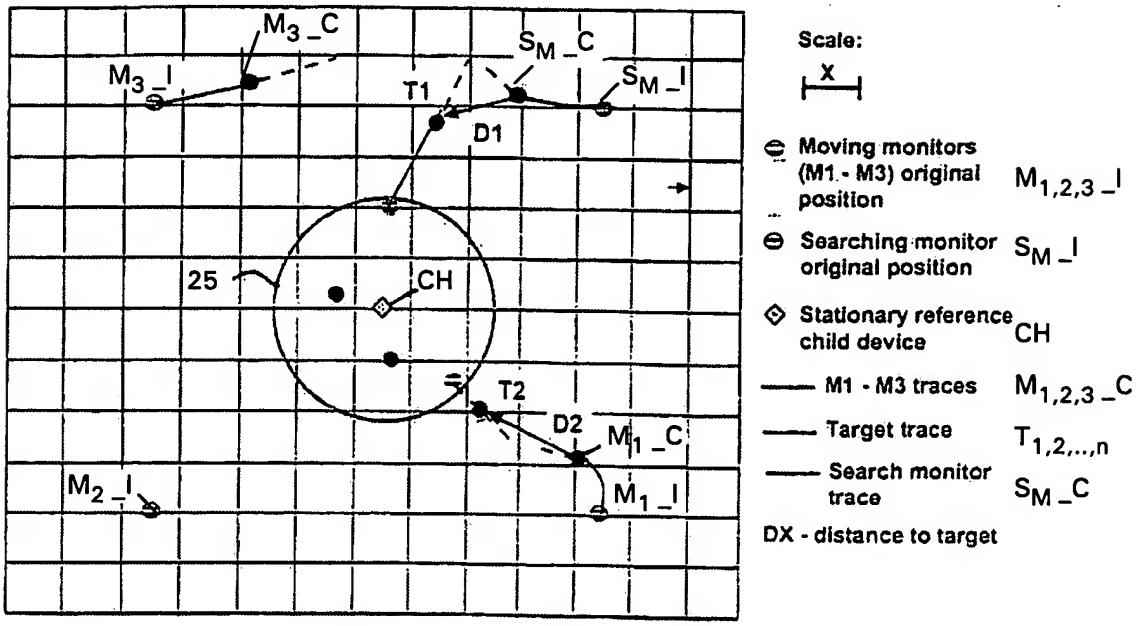
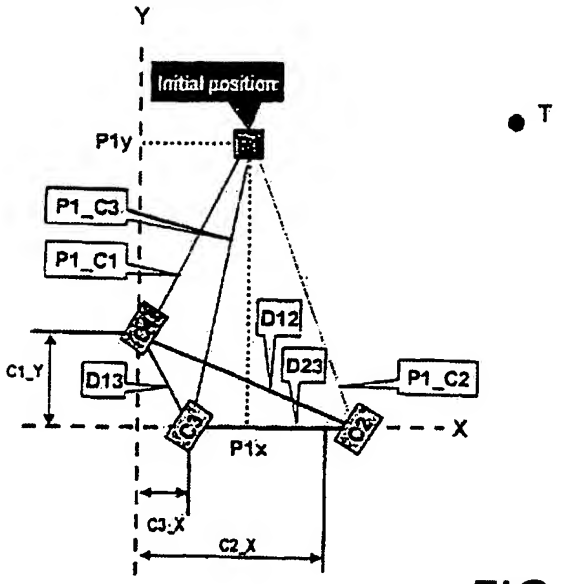


FIG. 19

Algorithm 2 homing. Three stationary child devices reference example
(virtual coordinates are rotated)



Every position and virtual X, Y coordinates are rotated. However, relative positions between all reference child devices searching monitor and target is unchanged

X, Y - virtual coordinates
C1, C2, C3 - positions of three stationary child reference monitors

Ck_Y, Ck_X - fixed child reference virtual coordinates are calculated from D12, D13 and D23 values

Pny, Pnx are calculated from Pn_Ck distances and C1-C3 coordinates

FIG. 20

Algorithm 2 homing. Three stationary child devices reference example, continued

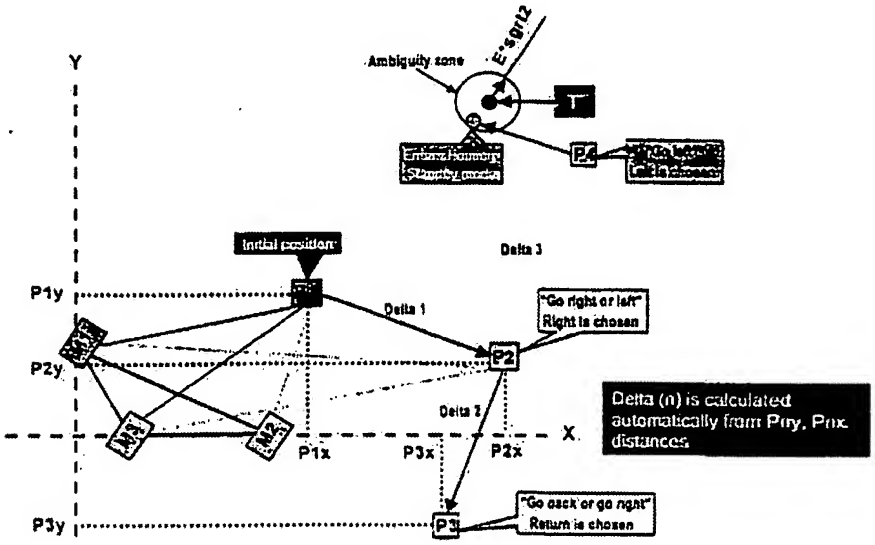


FIG. 21

Algorithm 2 homing. Three stationary child devices reference example, continued (obstacle avoidance/bypassing)

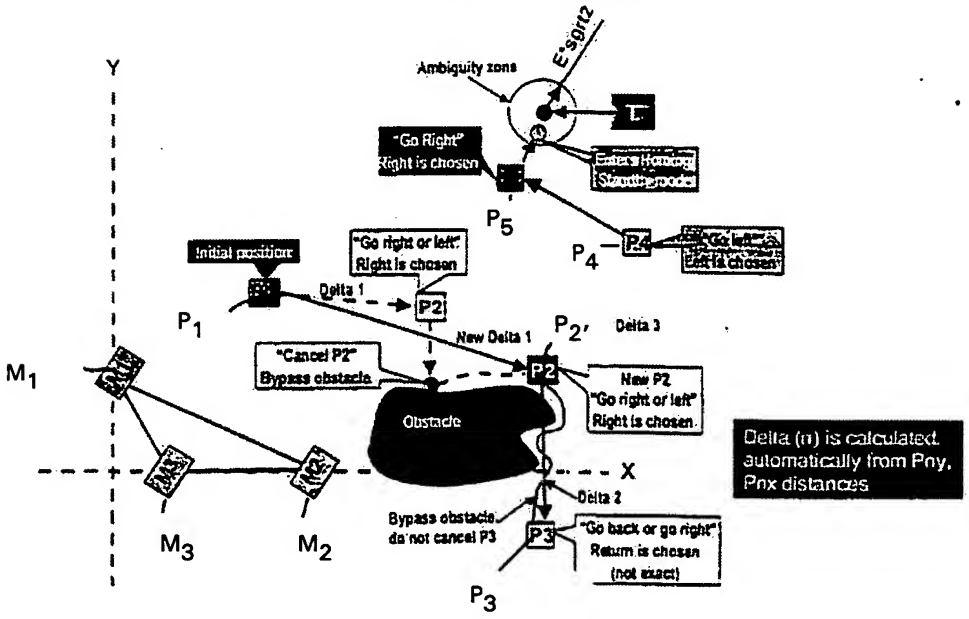


FIG. 22

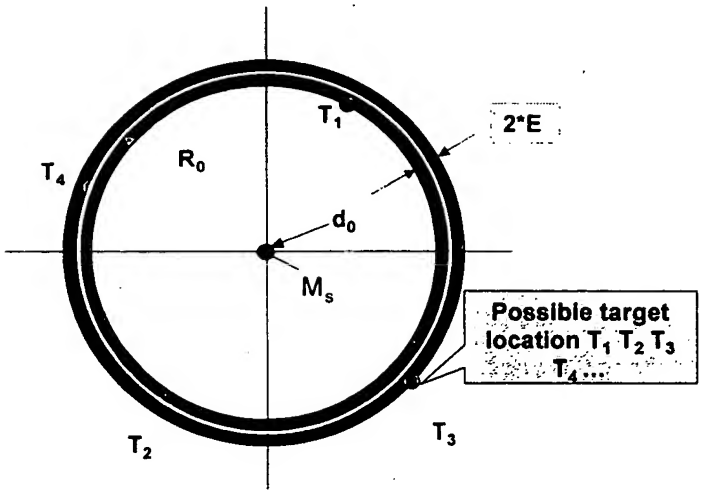

T1
2°E
T4
R0
d0
MS
Possible target location T1 T2 T3 T4 ...
T2
T3

FIG. 23

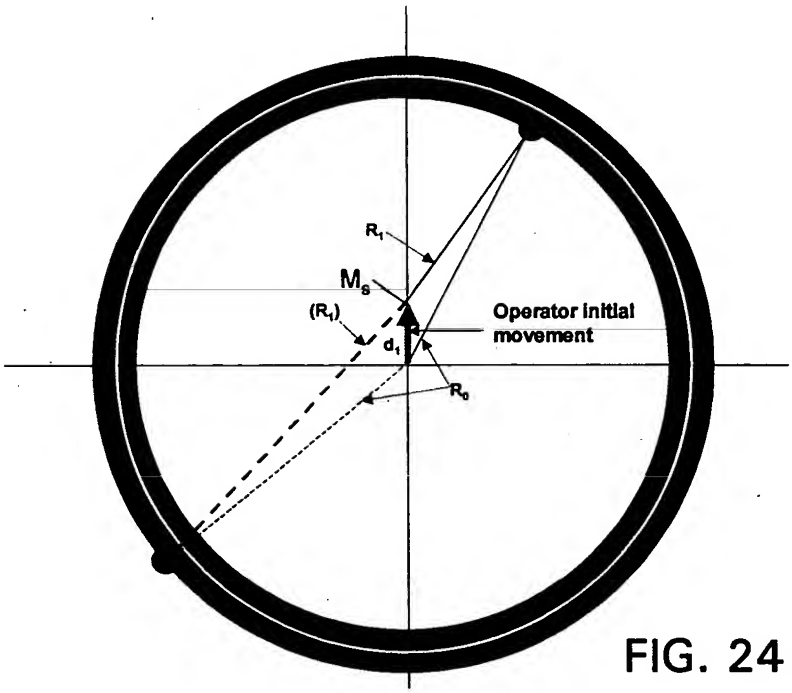

R1
MS
(R1)
Operator initial movement
d1
R0

FIG. 24

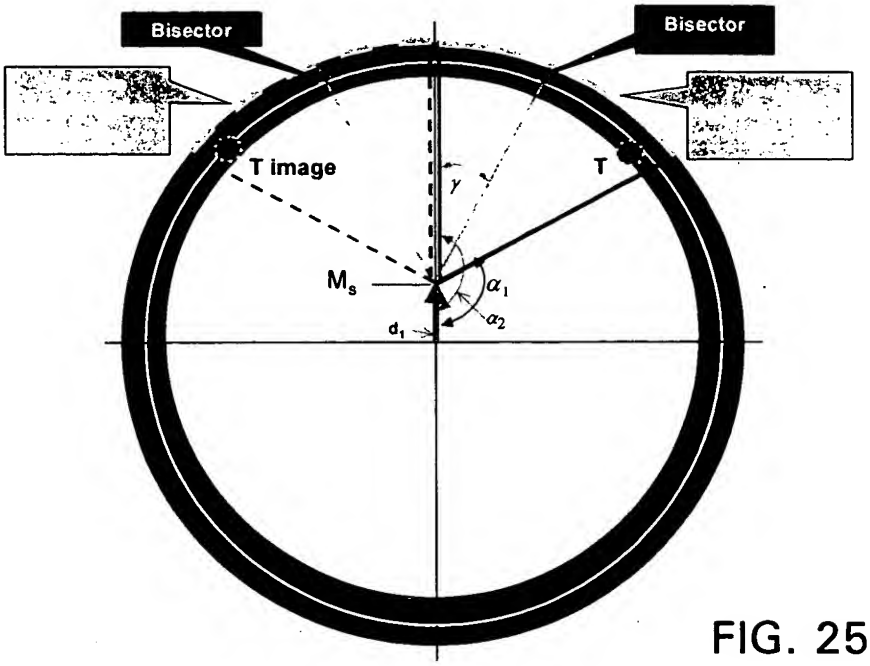

Bisector
Bisector
T image
T
γ
M_s
α_1
α_2
d_1

FIG. 25

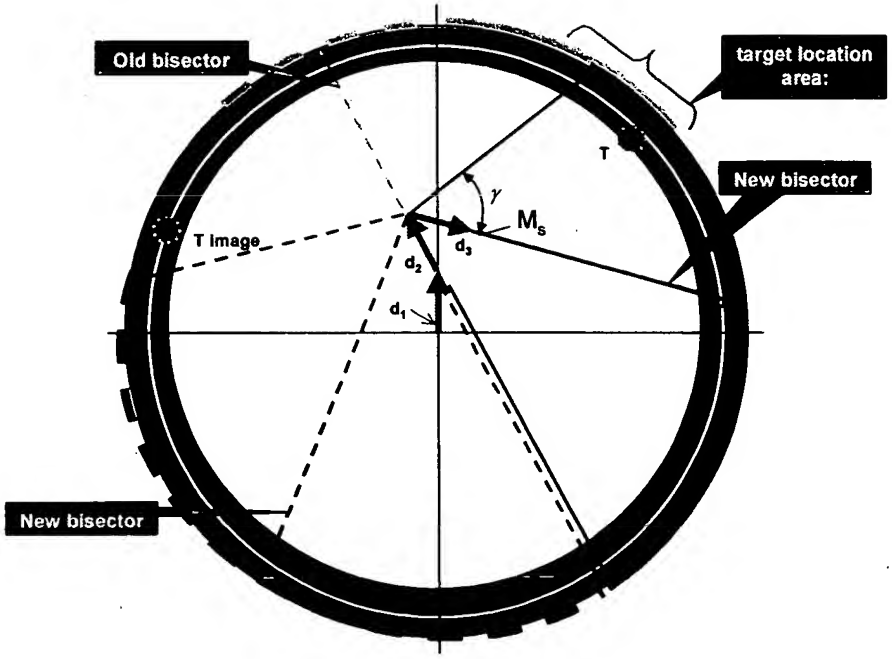

Old bisector
target location area:
T
New bisector
γ
M_s
T image
d_3
d_2
d_1
New bisector

FIG. 26

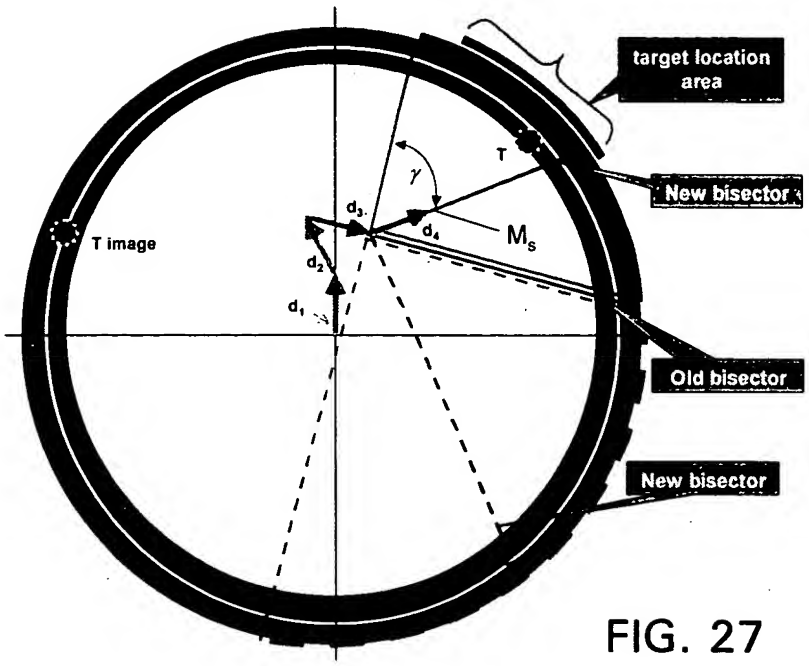

target location area
T
γ
New bisector
d3
d4
Ms
T image
d2
d1
Old bisector
New bisector

FIG. 27

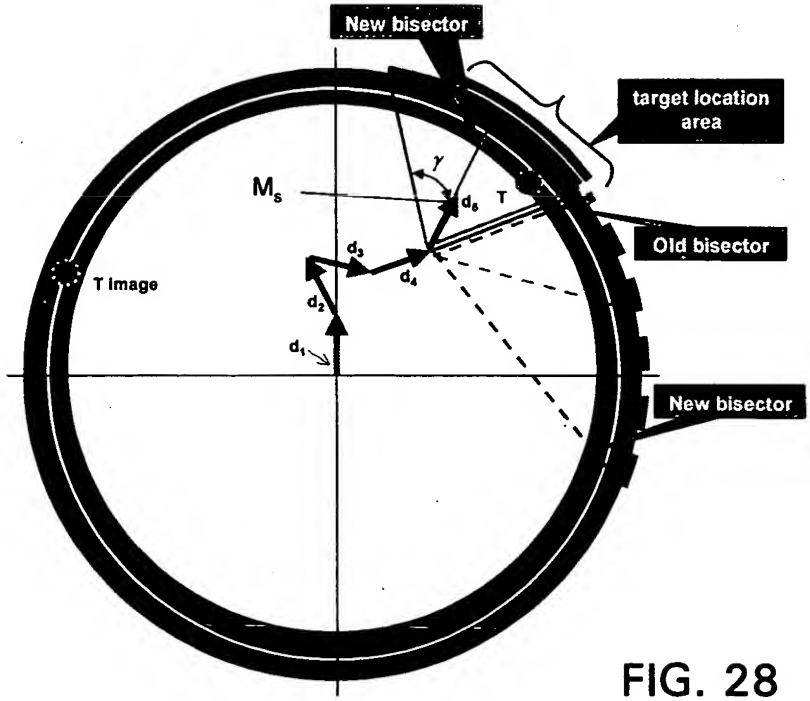

New bisector
target location area
γ
Ms
d5
T
Old bisector
d3
d4
T image
d2
d1
New bisector

FIG. 28

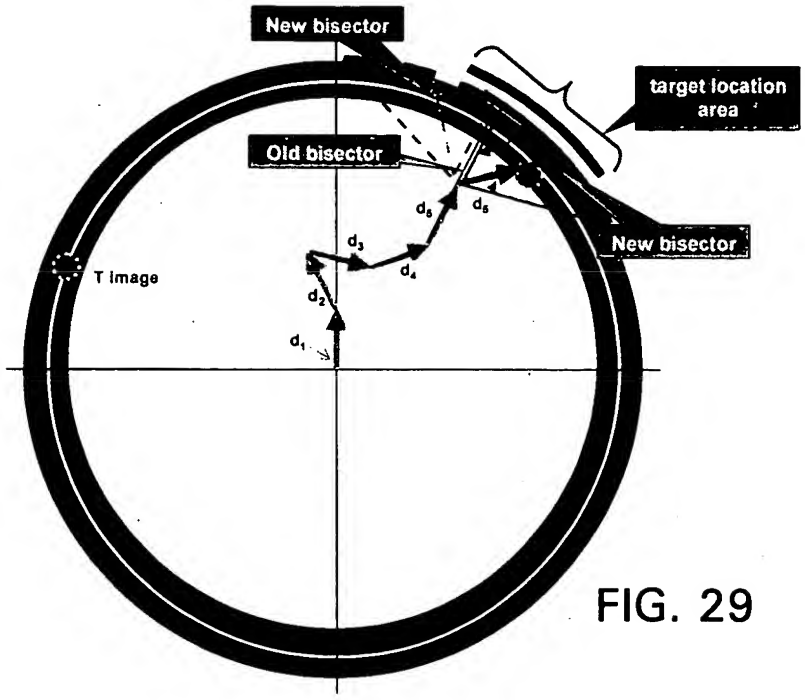

New bisector
target location area
Old bisector
New bisector
T image
d_1
d_2
d_3
d_4
d_5
d_6

FIG. 29

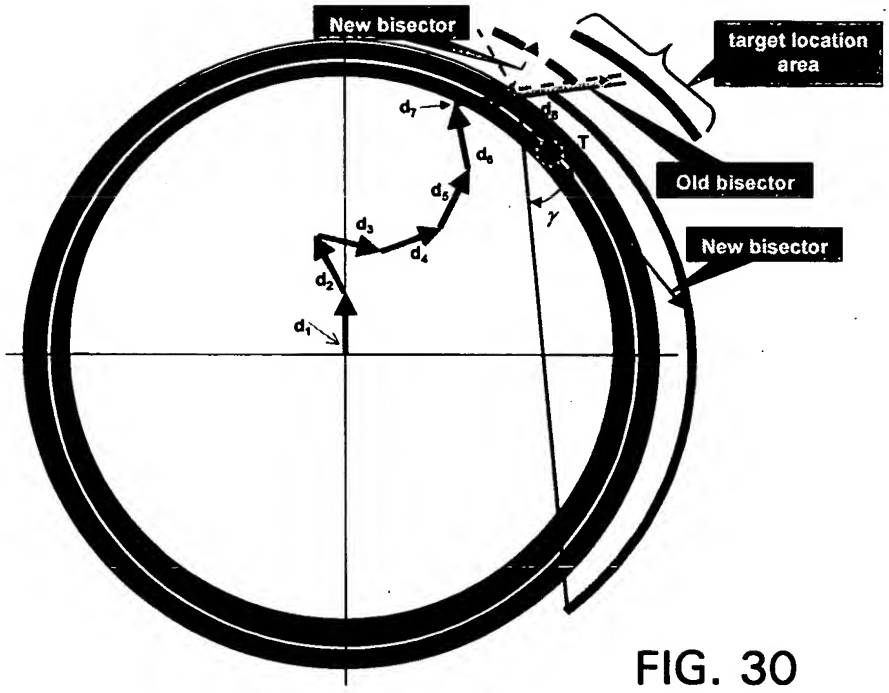

New bisector
target location area
Old bisector
New bisector
T
γ
d_1
d_2
d_3
d_4
d_5
d_6
d_7

FIG. 30

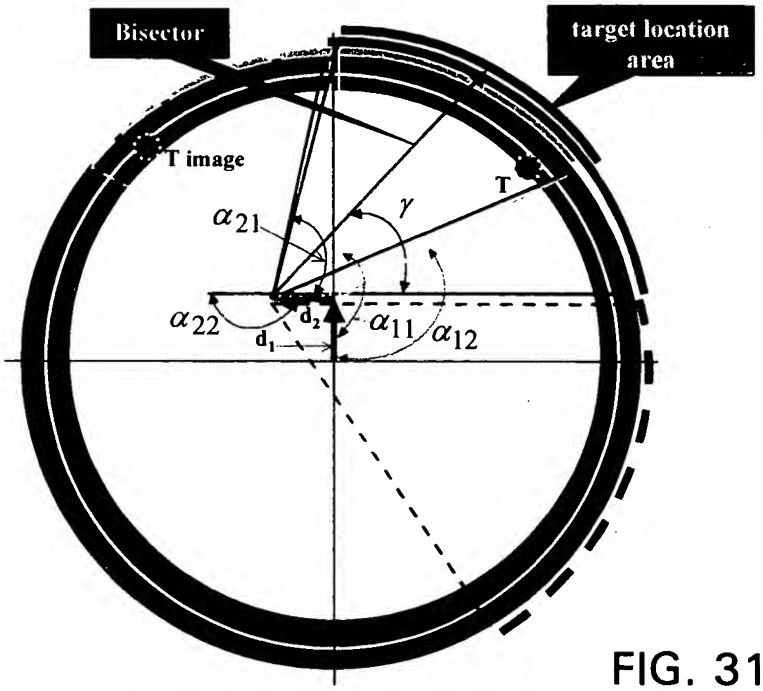

Bisector
target location area
T image
T
α_{21}
γ
α_{22}
d_2
d_1
α_{11}
α_{12}

FIG. 31

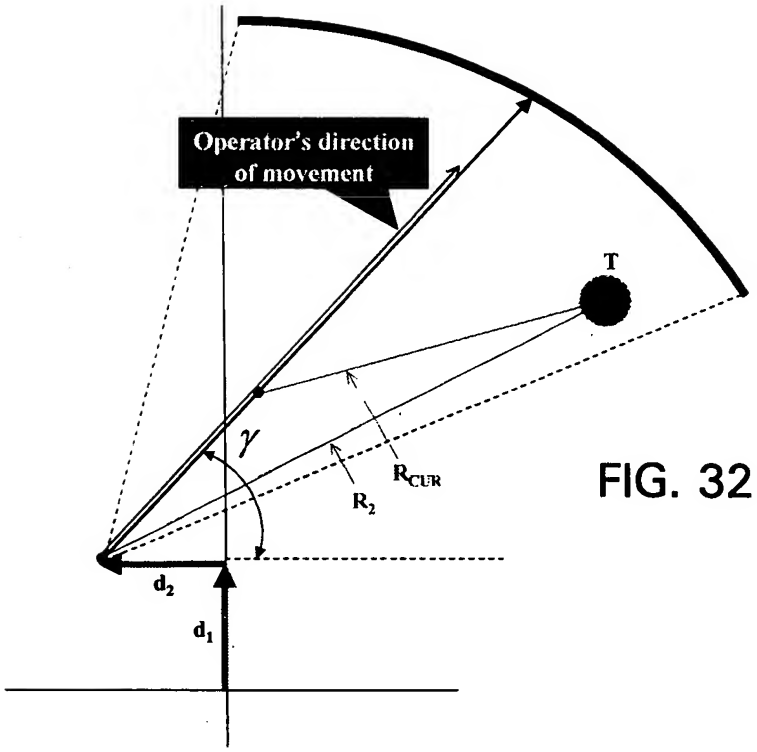

Operator's direction of movement
T
γ
R_{CUR}
R_2
d_2
d_1

FIG. 32

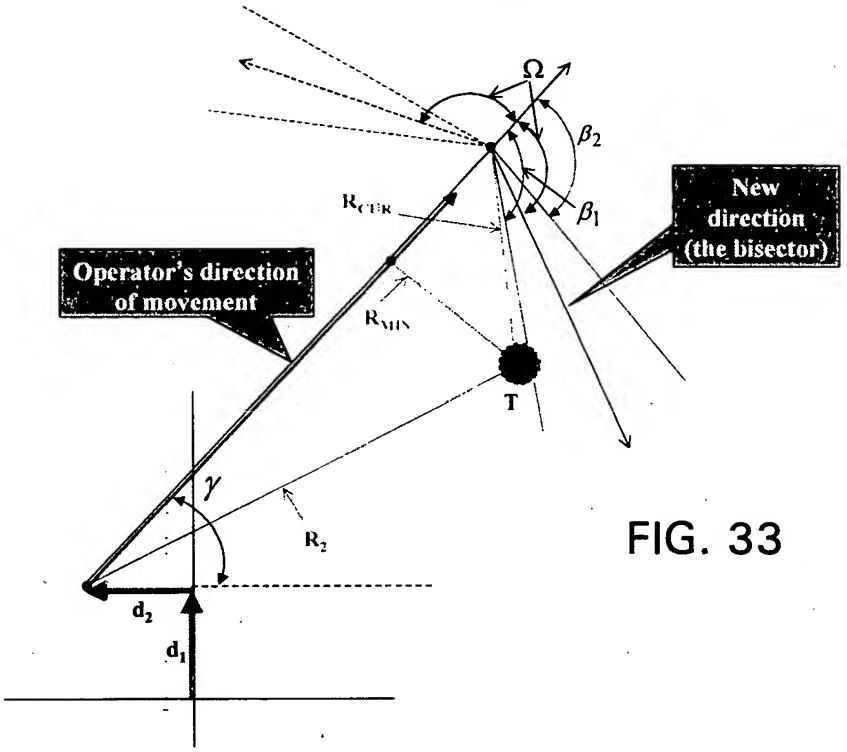

Ω
β_2
β_1
R_{CUR}
R_{MIN}
New direction (the bisector)
Operator's direction of movement
T
γ
R_2
d_2
d_1

FIG. 33

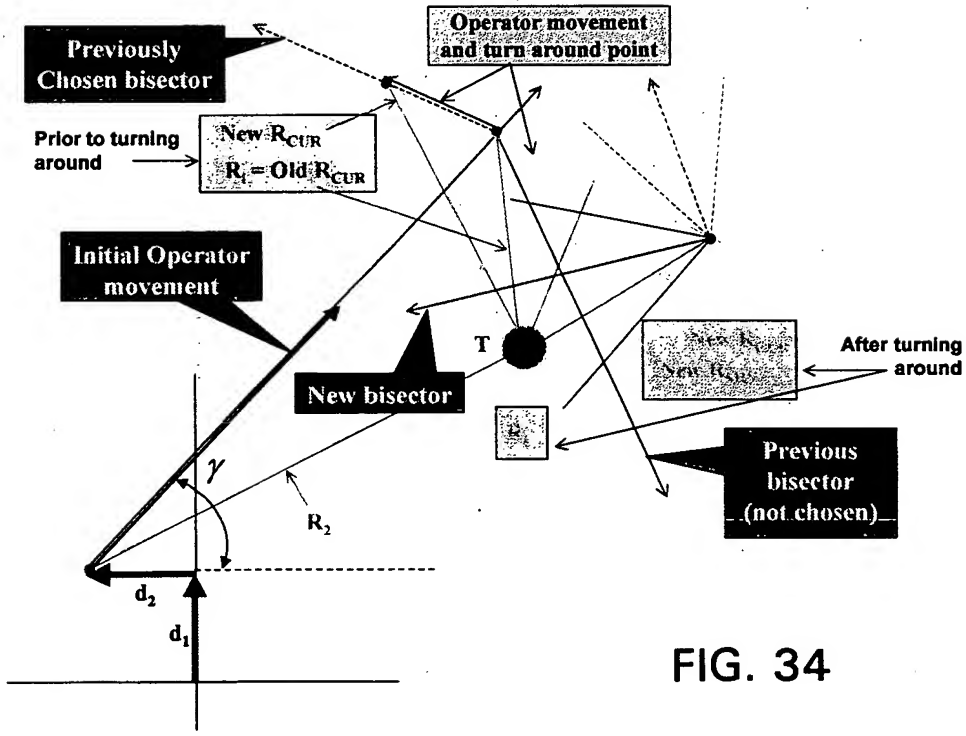

Previously Chosen bisector
Operator movement and turn around point
Prior to turning around
New R_{CUR}
R_1 = Old R_{CUR}
Initial Operator movement
T
After turning around
New bisector
Previous bisector (not chosen)
γ
R_2
d_2
d_1

FIG. 34

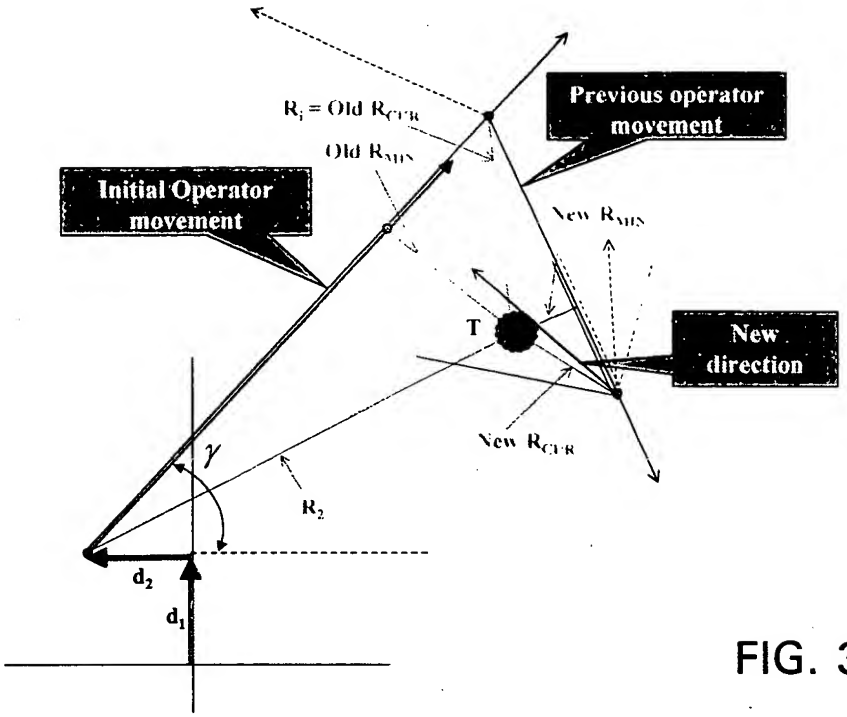

Previous operator movement
Initial Operator movement
New direction
T
γ
d_2
d_1
R_2

FIG. 35

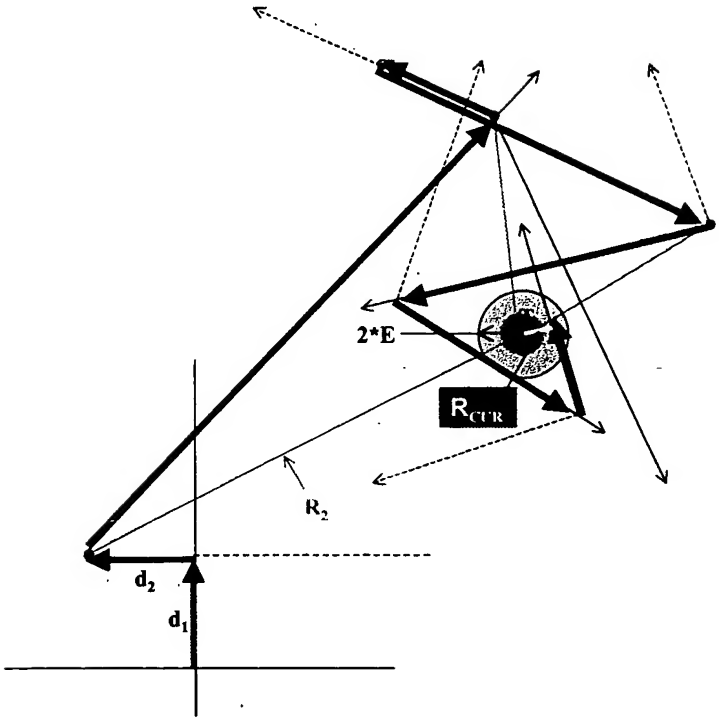
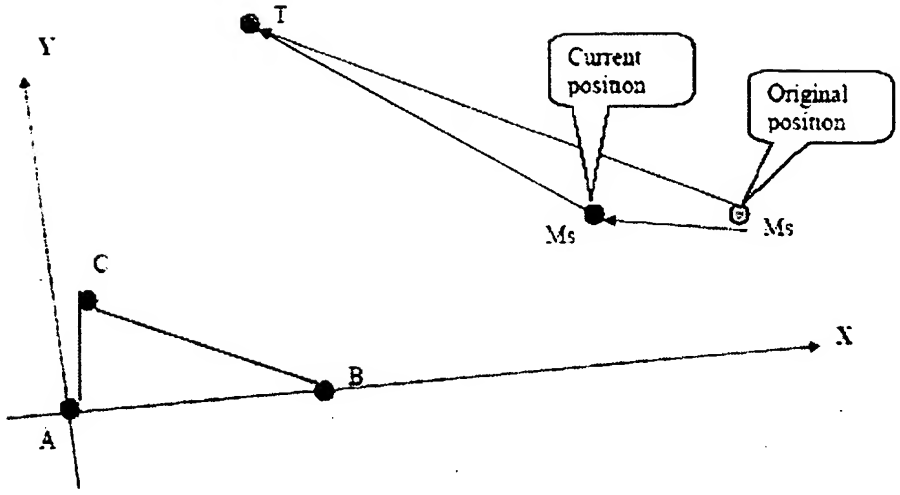
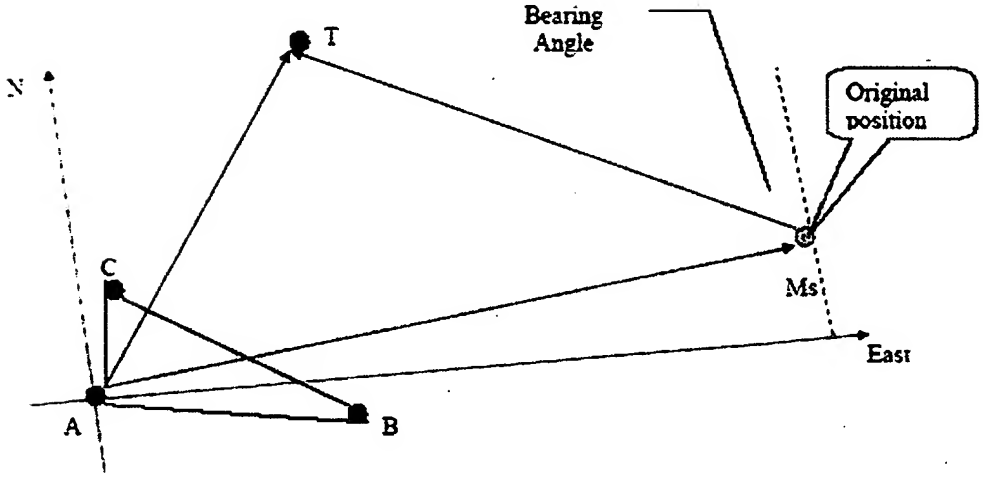

2*E
R_{CTR}
R_2
d_2
d_1

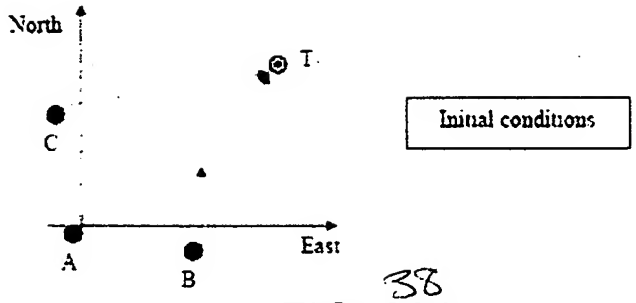
FIG. 36



37
FIG. 38A

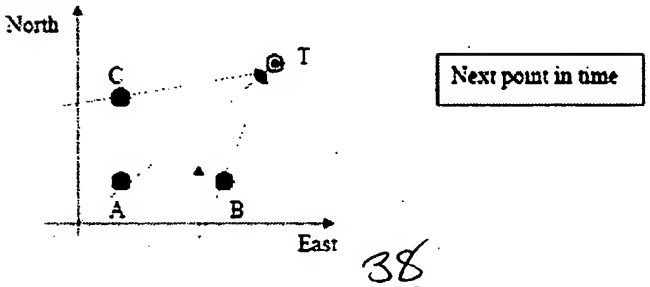


37
FIG. 38B



38

FIG. 39A



38

FIG. 39B

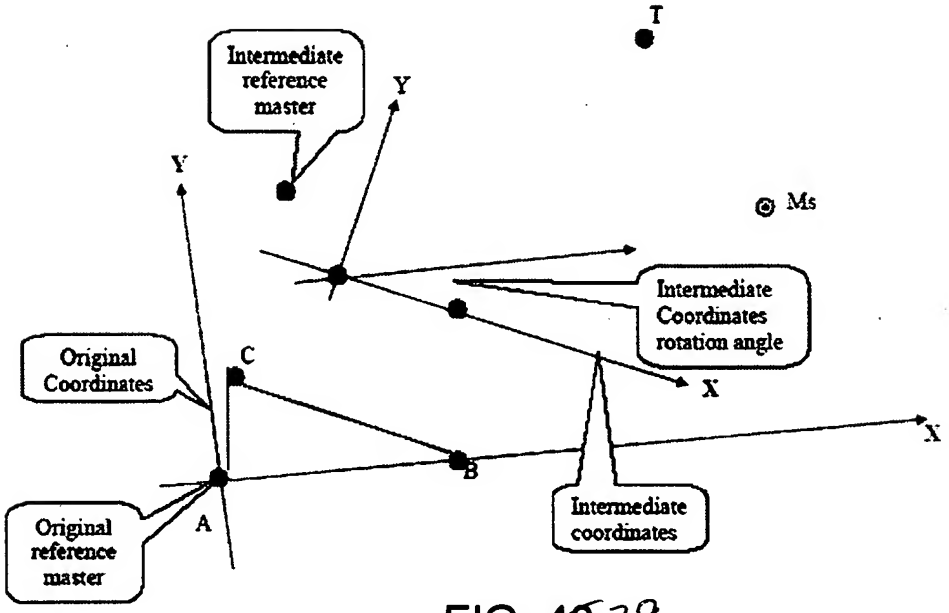


FIG. 40 39